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ENVIRONMENTAL RESEARCH INSTITUTE OF MICHIGAN

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Progress Report

for

NASA Contract NAS9-15476

ANALYSIS OF SCANNER DATA FOR CROP INVENTORIES

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Period Covered

7 March 1979 to 6 June 1979

ERIM Report Number 132400-24-P

PREFACE

The following report serves as the Quarterly Report for Contract NAS9-15476 which is entitled "Analysis of Scanner Data for Crop Inventories". This report describes the work carried out under that contract for the period 7 March 1979 through 6 June 1979.

Work on this contract is performed in the Infrared and Optics Division directed by Mr. Richard R. Legault. Dr. Quentin A. Holmes is the Program Manager for this contract and Mr. Robert Horvath is the Technical Manager.

This contract is part of a comprehensive and continuing program of research concerned with advancing the state-of-the-art in remote sensing of the environment from aircraft and satellites. The research is being carried out for NASA's Lyndon B. Johnson Space Center (JSC), Houston, Texas, by the Environmental Research Institute of Michigan (ERIM). The basic objective of this multidisciplinary program is to develop such information systems as practical tools which will provide planners and decision-makers extensive accurate information quickly and economically.

Substantive progress was made during the reporting period on all aspects of the current year's program. In order to clearly represent what was being accomplished and why, a somewhat unique format was used in orally presenting the ERIM work at the Supporting Research and Technology (S.R.&T.) Quarterly Review held at NASA/JSC on 4-6 June 1979. A running narrative was presented which simultaneously highlighted technical progress and showed the interrelationships between the various tasks and subtasks. This narrative was interspersed with six detailed technical presentations treating topics in greater depth. The materials which constitute this Quarterly Report are the visual aids in that presentation.

SECOND QUARTERLY PROGRESS REVIEW

ON

ANALYSIS OF MULTISPECTRAL SCANNER DATA FOR CROP INVENTORIES

CONTRACT NAS9-15476

ENVIRONMENTAL RESEARCH INSTITUTE OF MICHIGAN

PRESENTED AT

JOHNSON SPACE CENTER, HOUSTON, TEXAS

JUNE 1979

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CONTENTS/AGENDA

NARRATIVE PLUS SIX IN-DEPTH TOPICS

OVERALL LONG RANGE OBJECTIVE

OF

LARGE SCALE REMOTE SENSING

DEVELOPMENT OF GLOBAL ENVIRONMENTAL MONITORING AND MANAGEMENT SYSTEM

COMPONENTS OF AN ENVIRONMENT MONITORING AND MANAGEMENT SYSTEM

- INFORMATION SYSTEM
- FORECASTING SYSTEM
- DECISION-MAKING SYSTEM
- MANAGEMENT ACTIONS

- DEVELOPMENT OF THE INFORMATION SYSTEM USING REMOTELY SENSED AND COLLATERAL DATA IS TECHNOLOGICALLY REALIZABLE AND DRIVE OUR MAJOR RESEARCH GOALS.
- DEVELOPMENT OF OTHER SYSTEMS IS EQUALLY CRITICAL.
- CURRENT ACTIVITY IS DIRECTED TO MONITORING CROP PRODUCTION.

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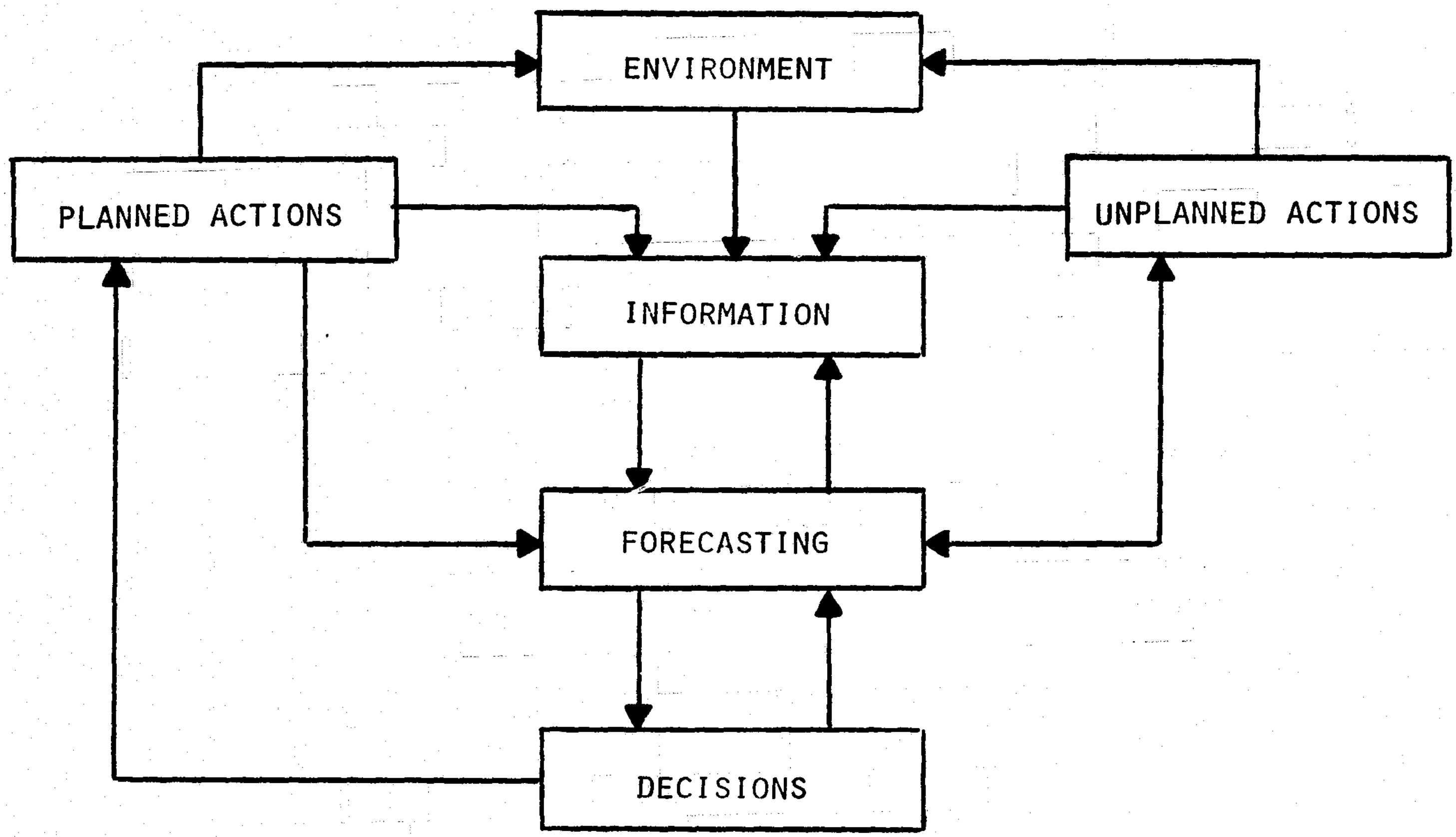

ENVIRONMENT MONITORING/MANAGEMENT SYSTEM

CONTRACT OBJECTIVE

ADVANCE THE STATE-OF-THE-ART IN EXTRACTING INFORMATION FROM REMOTELY SENSED MSS DATA AND COLLATERAL DATA, FOR THE PURPOSE OF CROP PRODUCTION FORECASTING

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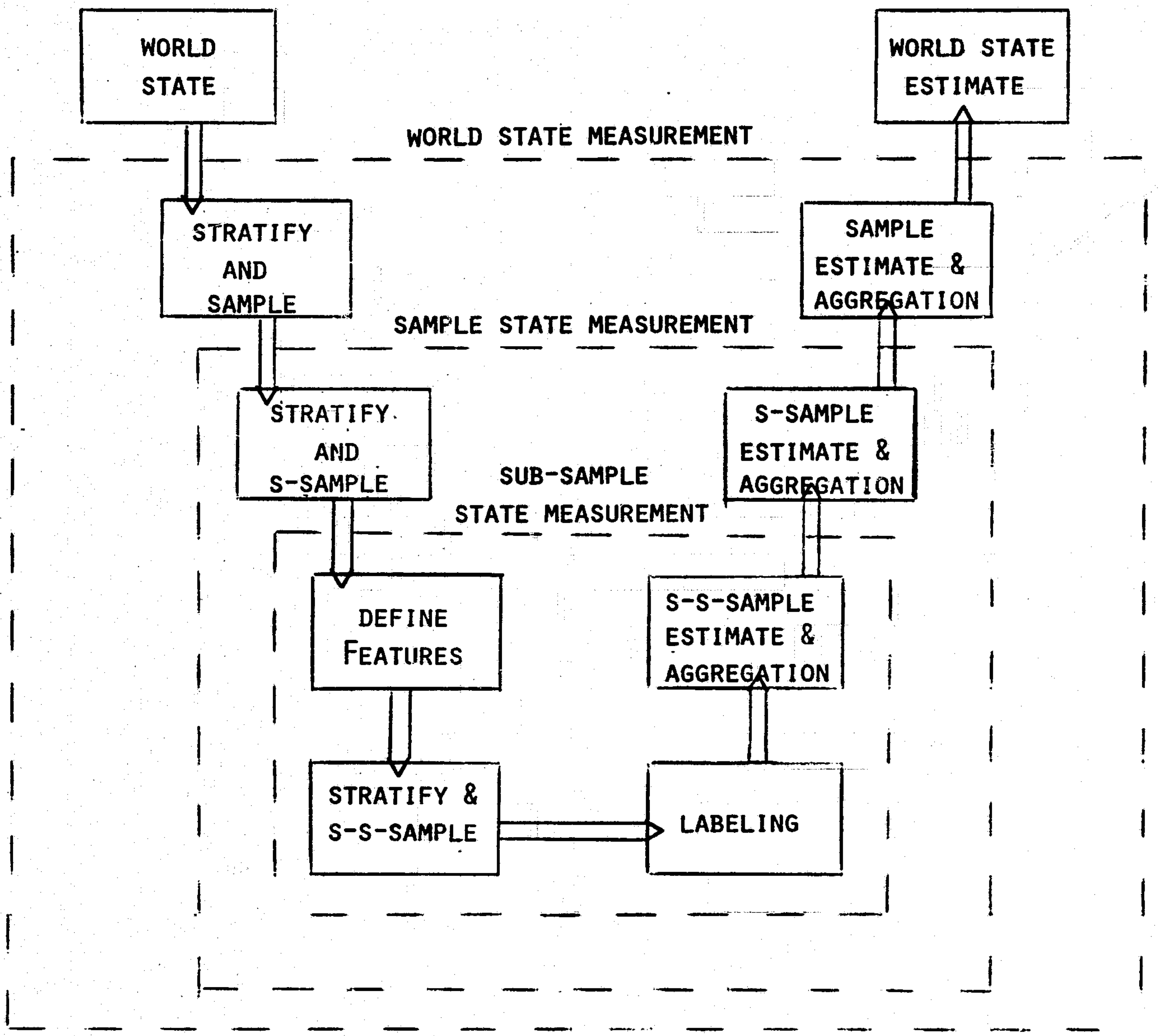
TASKS

- OBJECTIVE LABELING TECHNIQUE DEVELOPMENT
  - OBJECTIVE: DEVELOP THE TECHNOLOGY TO ACCURATELY AND OBJECTIVELY LABEL SCENE ELEMENTS BASED ON REMOTELY SENSED AND COLLATERAL DATA
- MACHINE PROCESSING TECHNIQUE DEVELOPMENT
  - OBJECTIVE: CREATE A MACHINE ENVIRONMENT FOR EFFECTIVE LABELING AND FOR THE EFFICIENT USE OF LABELS IN A LARGE-SCALE CROP PRODUCTION FORECASTING SYSTEM

CROP PRODUCTION INFORMATION SYSTEM



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SYNOPSIS OF TASKS

OBJECTIVE LABELING

- FEATURE DEFINITION
  - SPECTRAL/TEMPORAL/SPATIAL
  - LANDSAT DATA STRUCTURE
- SIGNATURE CHARACTERIZATION
  - CROP SPECIFIC/TEMPORAL TRAJECTORY STATISTICS/GENERALIZED SIGNATURES
- LABELING TECHNIQUES DEVELOPMENT
  - AI AIDS/MACHINE LABELING/UNDERSTANDING LABELING ERRORS

MACHINE PROCESSING

- DATA NORMALIZATION
  - LANDSAT CALIBRATION/ATMOSPHERE EFFECT CORRECTION
- STRATIFICATION, SAMPLING AND ESTIMATION
  - FIELD DEFINITION/BIAS AND VARIANCE REDUCTION
- ERROR MODEL DEVELOPMENT
  - SYSTEM ANALYSIS/PERFORMANCE MEASURES
- TEST AND EVALUATION
  - SYSTEM VERIFICATION/GENERATE NEW HYPOTHESES
- ADVANCED TECHNOLOGY
  - CRITICAL ANALYSIS OF FUTURE NEEDS

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OBJECTIVE LABELING TASK

- MAJOR ELEMENTS:
  - FEATURE DEFINITION
  - SIGNATURE CHARACTERIZATION
  - LABELING PROCEDURES AND TECHNIQUES
- FOCAL POINTS:
  - WINTER WHEAT
  - SPRING WHEAT AND OTHER SPRING SMALL GRAINS
  - TEMPORAL CHARACTERISTICS OF SPECTRAL DATA AND RELATIONSHIPS WITH COLLATERAL DATA

ELEMENTS OF OBJECTIVE LABELING

- FEATURE DEFINITION
  - UNDERSTAND STRUCTURE AND CHARACTERISTICS OF SPECTRAL DATA
  - DETERMINE FEATURES EXTRACTABLE FROM LANDSAT AND COLLATERAL DATA
  - DETERMINE AGRONOMIC AND PHYSIOLOGICAL SIGNIFICANCE AND INFORMATION POTENTIAL OF FEATURES
- SIGNATURE CHARACTERIZATION
  - DEVELOP GENERALIZED METHODS FOR DESCRIBING FEATURES
  - DEVELOP NORMALIZATION PROCEDURES
  - SELECT FEATURES AND UNDERSTAND INTERRELATIONSHIPS
- LABELING TECHNIQUE DEVELOPMENT
  - DEVELOP IMPROVED IMAGE PRODUCTS AND LABELING AIDS
  - DEVELOP OBJECTIVE LABELING PROCEDURES
  - EXAMINE LABELING ERROR PATTERNS

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FEATURE DEFINITION

OBJECTIVE

DERIVE OR DETERMINE DISCRIMINATIVE FEATURES FOR USE IN LABELING SCENE ELEMENTS AS TO THEIR CROP TYPE

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FEATURE DEFINITION

Approach

Understand Temporal Characteristics of Spectral Data From Wheat

- Study crop characteristics
- Generate and analyze simulation data
- Analyze field measurement data
- Analyze Landsat data

Understand the Structure of Landsat Data

- Develop relationships between in-band reflectances and Landsat data
- Study relationships between:
  - Landsat bands
  - Landsat band ratios
  - Combinations of bands, such as the Tasseled-Cap variables

FEATURE DEFINITION

APPROACH (CONTINUED)

DEFINE FEATURES FOR CROP DETECTION AND IDENTIFICATION

- TIME PROFILES DEPICTING GREEN DEVELOPMENT
- TIME PROFILES DEPICTING CROP RIPENING AND MATURATION
- DISTINCTIVE CHARACTERISTICS OF THOSE PROFILES, E.G.:
  - .. PEAK GREEN AND DAY OF OCCURRENCE
  - .. DAY OF EMERGENCE, HARVEST, ETC.
  - .. RATES OF GREEN-UP AND SENESCENCE
- CONTEXTUAL FEATURES

DETERMINE AGRONOMIC AND PHYSIOLOGICAL SIGNIFICANCE OF FEATURES

- AGRICULTURAL PRACTICES
- SOIL EFFECTS
- DROUGHT AND OTHER STRESSES
- RELATIONSHIPS TO COLLATERAL DATA

FEATURE DEFINITION

PROGRESS

- UNDERSTANDING TEMPORAL CHARACTERISTICS OF WHEAT SPECTRA
  - FORMULATED SPECTRAL PHENOLOGY MODEL
  - BEGAN ANALYSIS OF USDA/PHOENIX REFLECTANCE MEASUREMENTS
- UNDERSTANDING RELATIONSHIPS WITHIN AND BETWEEN SPECTRAL DATA SPACES
  - STUDIED LANDSAT BANDS AND BAND RATIOS VS. TASSELED-CAP VARIABLES
  - RELATED IN-BAND REFLECTANCES TO LANDSAT BANDS

TEMPORAL CHARACTERISTICS OF WHEAT SPECTRA

WILLIAM A. MALILA

TEMPORAL CHARACTERISTICS OF WHEAT SPECTRA

OBJECTIVES

- TO DEVELOP DISCRIMINATIVE FEATURES FROM WHEAT SPECTRAL DATA ACQUIRED THROUGHOUT THE GROWING SEASON
- TO DEVELOP IMPROVED UNDERSTANDING OF THE SPECTRAL CHARACTERISTICS OF WHEAT, AS A FUNCTION OF:
  - DATE AND CROP CALENDAR
  - OBSERVATION CONDITIONS
  - METEOROLOGICAL PARAMETERS
  - AGRONOMIC FACTORS

APPROACH

- ANALYZE AVAILABLE DATA
  - FIELD MEASUREMENT DATA
  - LANDSAT DATA FROM LACIE AND LACIE-TRANSITION SITES
- SYNTHESIZE AND BEGIN TO USE A SPECTRAL PHENOLOGY MODEL FOR WHEAT

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APPROACH TO SPECTRAL PHENOLOGY MODEL FOR WHEAT

- FORMULATE OVERALL STRUCTURE
- ACQUIRE STATE-OF-THE-ART (SOA) OR NEAR-SOA SUBMODELS
  - WHEAT GROWTH MODEL
  - CROP REFLECTANCE MODEL
  - ATMOSPHERIC EFFECTS MODEL
  - SENSOR MODEL
  - PREPROCESSING MODEL
- DEVELOP REQUIRED INTERFACES
- OBTAIN INPUT AND TEST DATA
- IMPLEMENT AND TEST THE SYNTHESIZED MODEL
- BEGIN USE OF THE MODEL IN DEVELOPING OBJECTIVE TECHNIQUES FOR LABELING MULTISPECTRAL SCANNER DATA
- UPDATE AS IMPROVED SUBMODELS BECOME AVAILABLE

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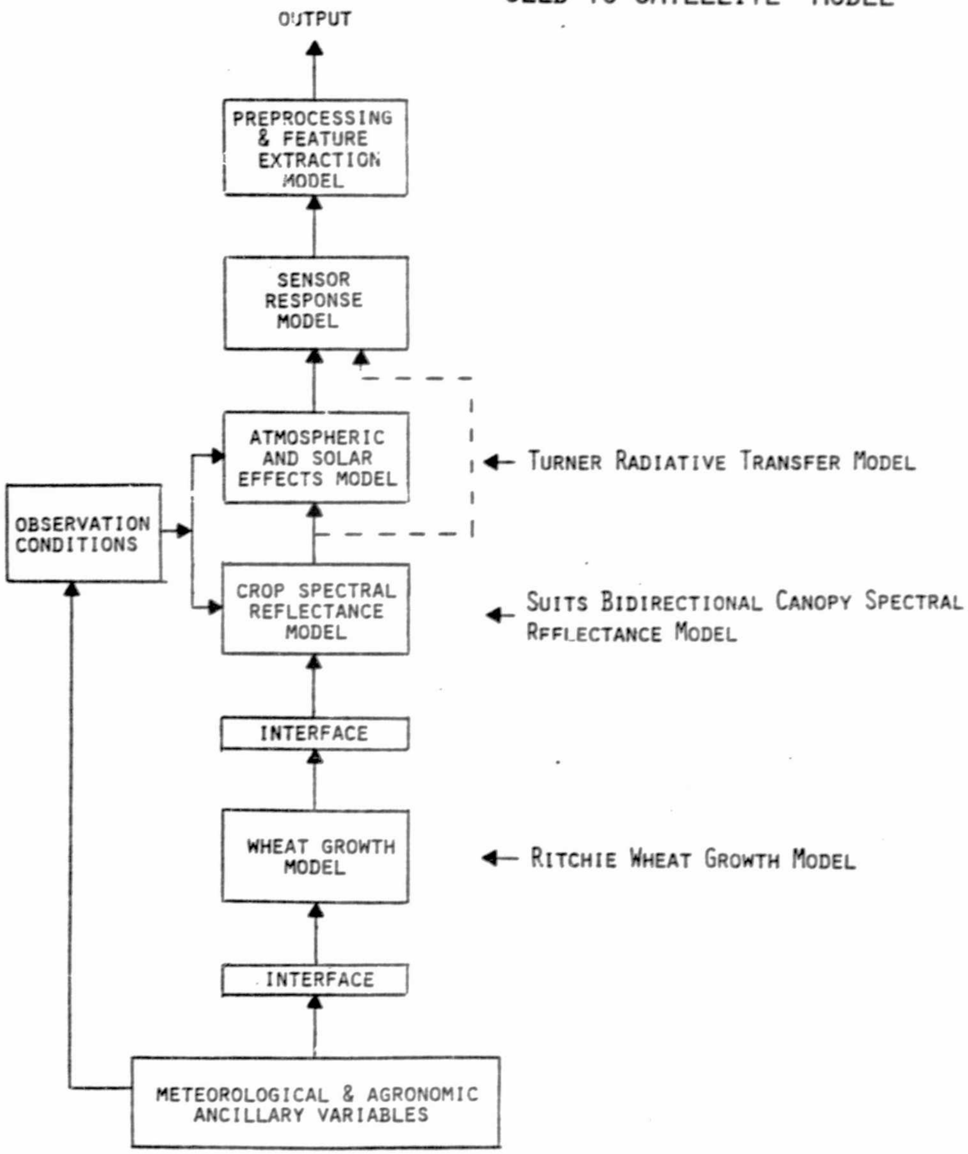
"SEED-TO-SATELLITE" MODEL



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PLANNED ACTIVITIES (18 MONTHS)

- SYNTHESIS OF THE MODEL
- TESTING AND VALIDATION, USING:
  - USDA FIELD MEASUREMENT DATA
  - LACIE FIELD MEASUREMENT DATA
  - POSSIBLY, LACIE INTENSIVE TEST SITE DATA
- ACQUISITION OF METEOROLOGICAL DATA (E.G., OVER 30 YEARS)
  - DAILY MAXIMUM AND MINIMUM TEMPERATURES
  - DAILY PRECIPITATION
  - SOLAR RADIATION OR CLOUD COVER, AS AVAILABLE
- PRINCIPAL COMPONENT CHARACTERIZATION OF METEOROLOGICAL DATA SHOULD PROVIDE
  - BASELINE SCENARIO
  - LIMITED NUMBER OF DEVIANT SCENARIOS, YET REPRESENTATIVE OF MAJOR VARIABILITY

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ANALYSIS OF FIELD MEASUREMENT DATA

DATA SET DETERMINATION

- MEASURED AND PROVIDED BY:
  - DR. RAYMOND JACKSON, ET AL, USDA
  - U.S. WATER CONSERVATION LABORATORY, PHOENIX, ARIZONA
- EXPERIMENT DESIGNED TO DETERMINE WATER STRESS EFFECTS ON WHEAT YIELD (1977-1978 GROWING SEASON)
- EXPERIMENT FACTORS
  - MOISTURE TREATMENT: SIX LEVELS OF IRRIGATION
  - CROP: TWO WHEAT VARIETIES AND ONE BARLEY
    (NOTE: PLANTING DENSITIES GREATER THAN NORMAL FOR N. GREAT PLAINS)
- SPECTRAL MEASUREMENTS
  - HAND-HELD LANDSAT-BAND RADIOMETER
  - DAILY MEASUREMENTS, WEATHER PERMITTING
- AGRONOMIC MEASUREMENTS
  - CROP GROWTH STAGE (MODIFIED FEEKES SCALE)
  - LEAF AREA
  - STEM LENGTH
  - WET AND DRY WEIGHTS

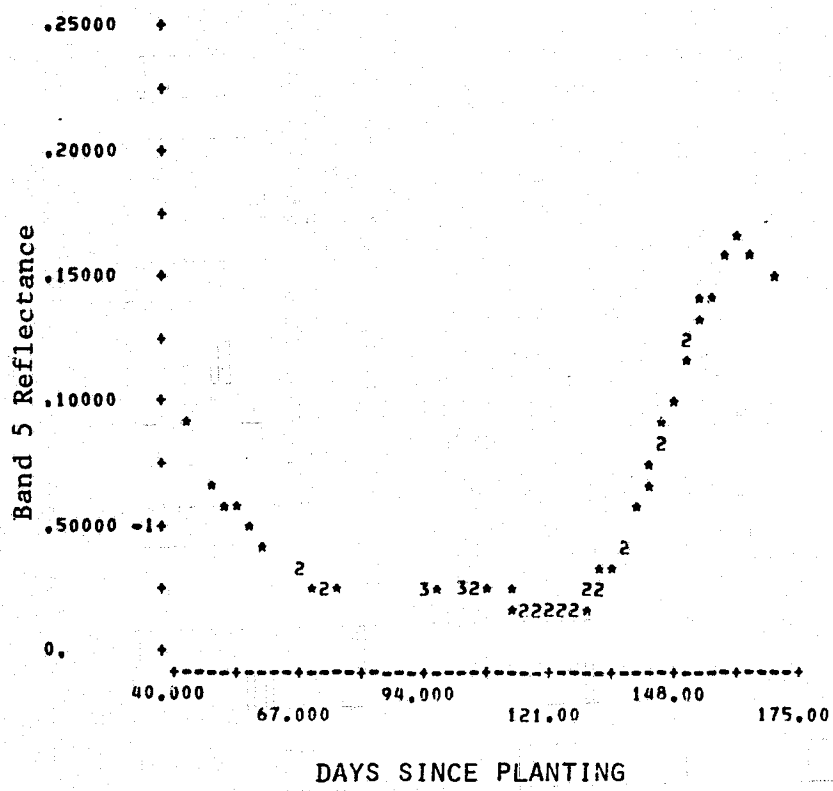
ANALYSIS OBJECTIVES BEARING ON CHOICE OF FEATURES FOR DISCRIMINATION

- To DETERMINE SPECTRAL DEPENDENCE ON GROWTH STAGE AND DATE
- To DEVELOP IMPROVED METHODS FOR INTERPRETING REFLECTANCE DATA PATTERNS
- To DETERMINE CHARACTERISTICS OF GREEN MEASURES

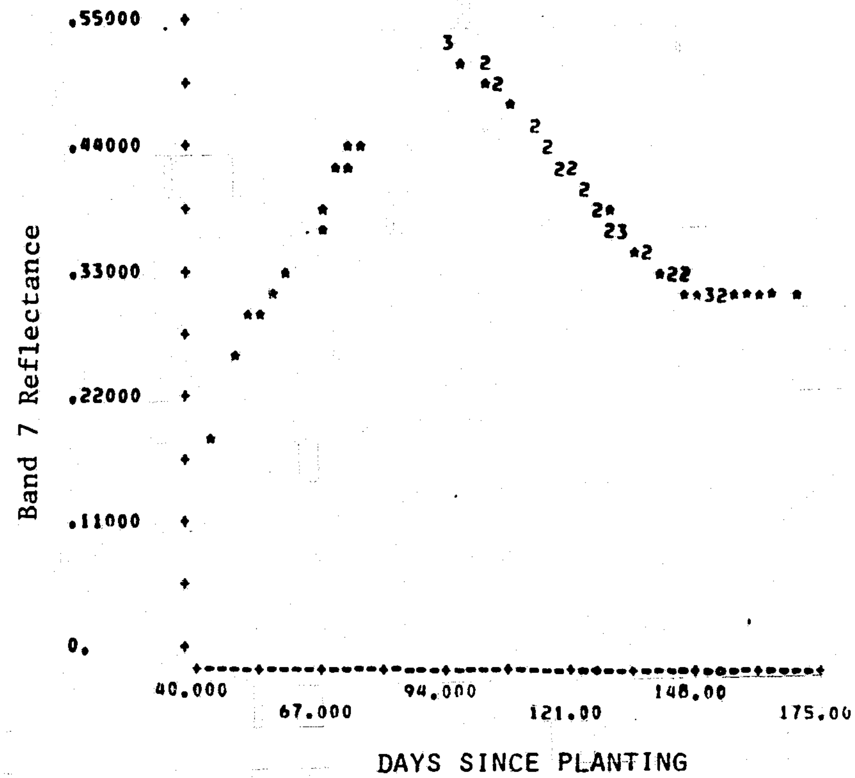
TEMPORAL PATTERN OF REFLECTANCE IN TWO BANDS

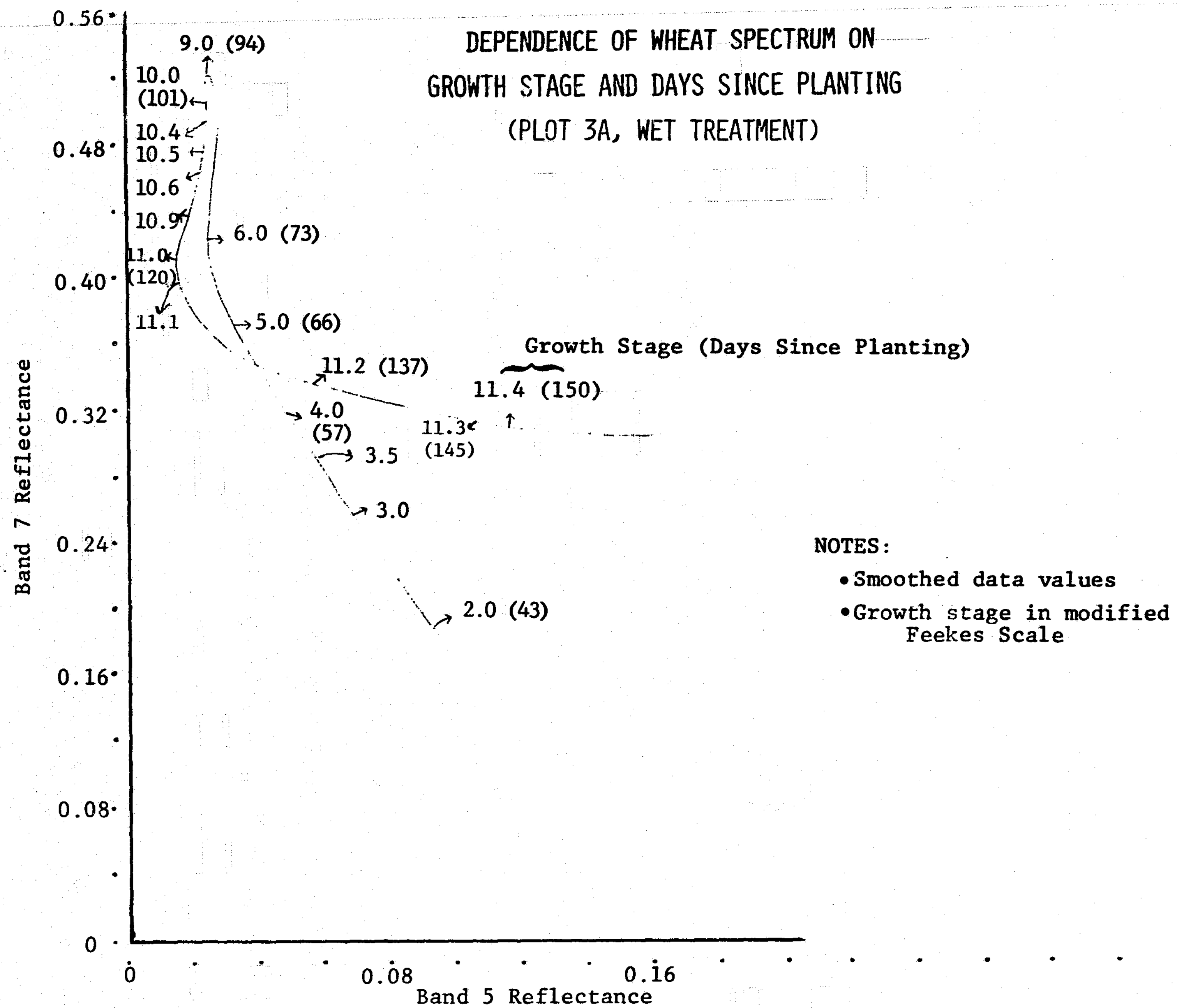
(PLOT 3A, WET TREATMENT, SMOOTHED DATA)

BAND 5 REFLECTANCE

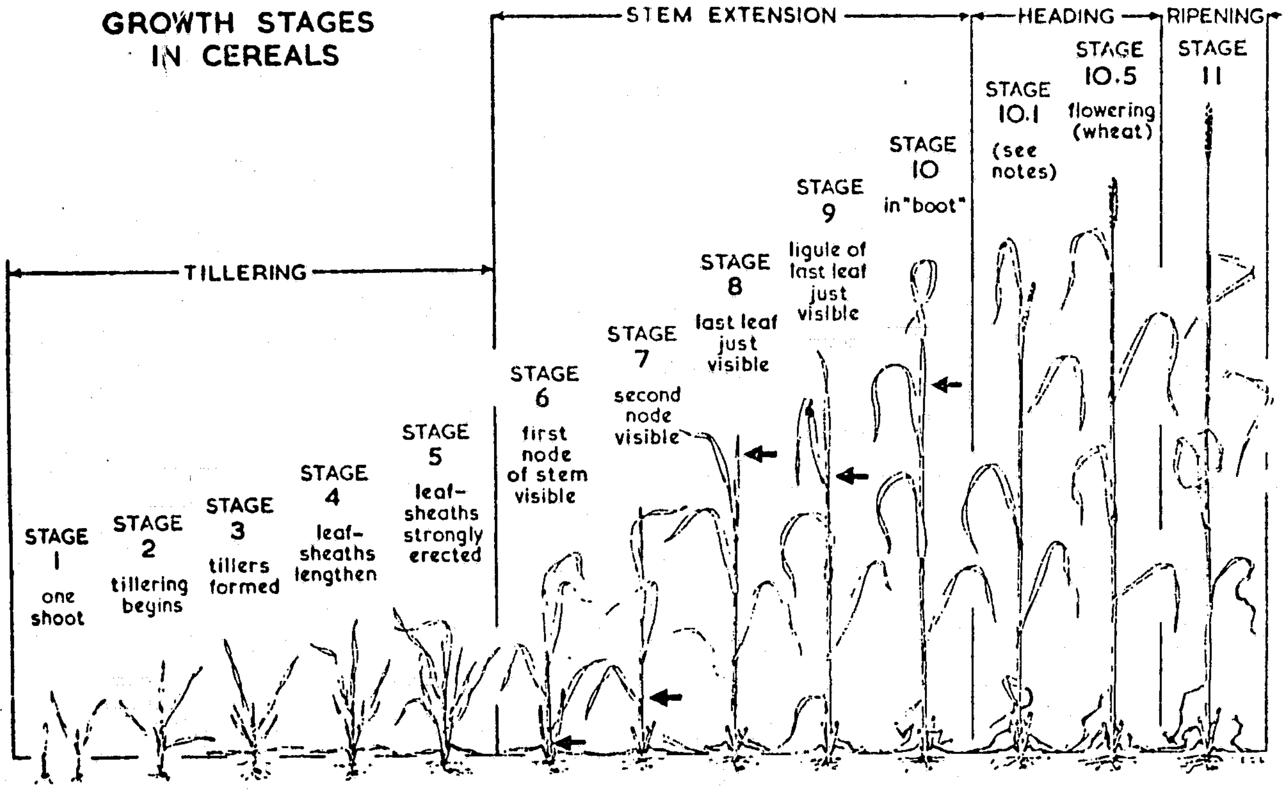


BAND 7 REFLECTANCE



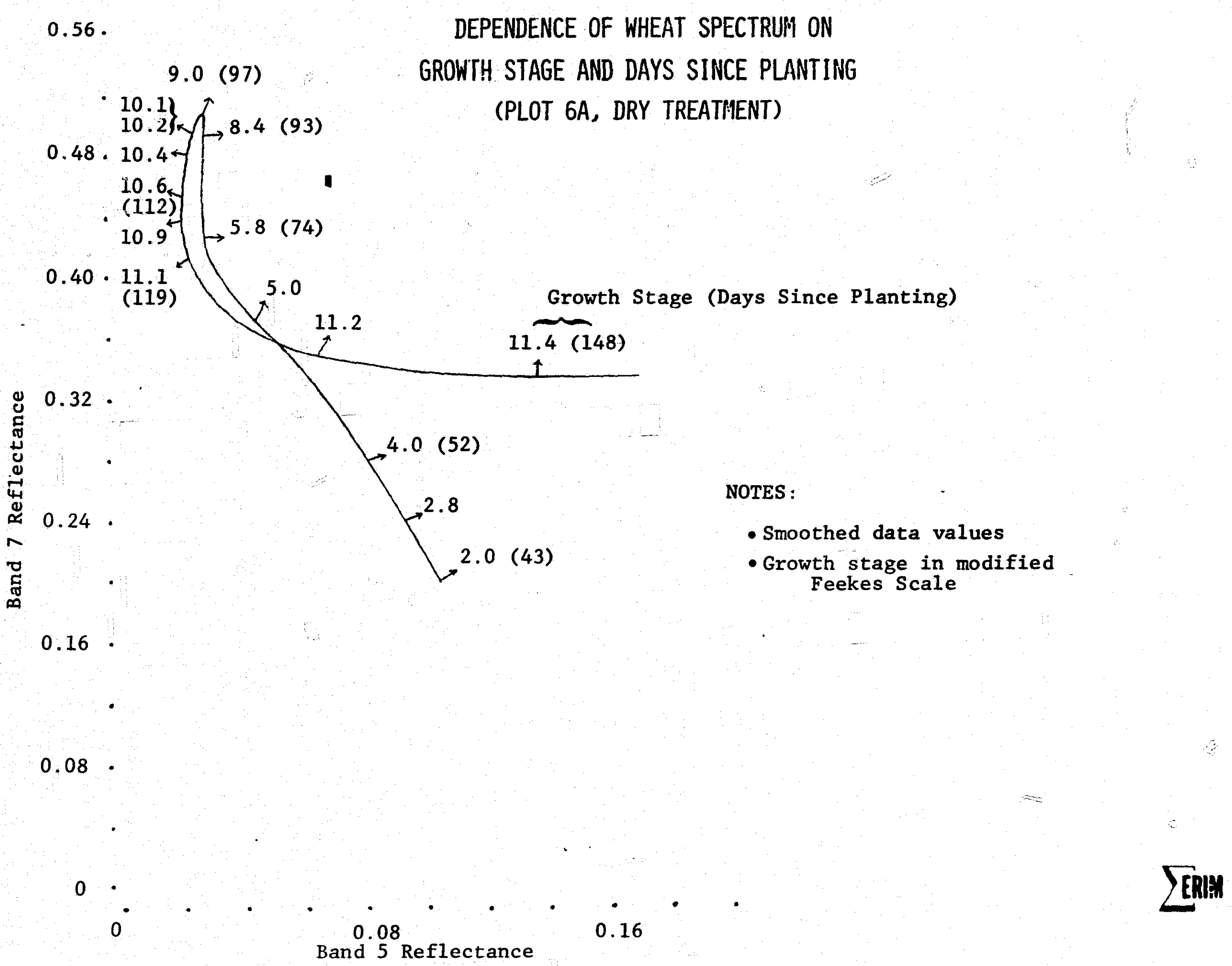


DEPENDENCE OF WHEAT SPECTRUM ON
GROWTH STAGE AND DAYS SINCE PLANTING
(PLOT 3A, WET TREATMENT)
Growth Stage (Days Since Planting)
9.0 (94)
10.0 (101)
10.4
10.5
10.6
10.9
11.0 (120)
11.1
6.0 (73)
5.0 (66)
11.2 (137)
11.4 (150)
11.3 (145)
4.0 (57)
3.5
3.0
2.0 (43)
NOTES:
• Smoothed data values
• Growth stage in modified Feekes Scale
Band 7 Reflectance
0.56
0.48
0.40
0.32
0.24
0.16
0.08
0
Band 5 Reflectance
0
0.08
0.16



Stage		
1	One shoot (number of leaves can be added) = 'brairding'	Tillering
2	Beginning of tillering	
3	Tillers formed, leaves often twisted spirally. In some varieties of winter wheats, plants may be 'creeping' or prostrate	
4	Beginning of the erection of the pseudo-stem, leaf-sheaths beginning to lengthen	
5	Pseudo-stem (formed by sheaths of leaves) strongly erected	
6	First node of stem visible at base of shoot	Stem Extension
7	Second node of stem formed, next-to-last leaf just visible	
8	Last leaf visible, but still rolled up; ear beginning to swell	
9	Ligule of last leaf just visible	
10	Sheath of last leaf completely grown out, ear swollen but not yet visible	
10.1	First ears just visible (awns just showing in barley, ear escaping through split of sheath in wheat or oats)	Heading
10.2	Quarter of heading process completed	
10.3	Half of heading process completed	
10.4	Three-quarters of heading process completed	
10.5	All ears out of sheath	
10.5.1	Beginning of flowering (wheat)	Flowering (Wheat)
10.5.2	Flowering complete to top of ear	
10.5.3	Flowering over at base of ear	
10.5.4	Flowering over, kernel watery-ripe	
11.1	Milky-ripe	Ripening
11.2	Mealy-ripe, contents of kernel soft but dry	
11.3	Kernel hard (difficult to divide by thumb-nail)	
11.4	Ripe for cutting. Straw dead	

MODIFIED FEEKES SCALE


DEPENDENCE OF WHEAT SPECTRUM ON
GROWTH STAGE AND DAYS SINCE PLANTING
(PLOT 6A, DRY TREATMENT)
Band 7 Reflectance
0.56
0.48
0.40
0.32
0.24
0.16
0.08
0
Band 5 Reflectance
0
0.08
0.16
9.0 (97)
10.1
10.2
8.4 (93)
10.4
10.6
(112)
5.8 (74)
10.9
11.1
(119)
5.0
11.2
Growth Stage (Days Since Planting)
11.4 (148)
4.0 (52)
2.8
2.0 (43)
NOTES:
• Smoothed data values
• Growth stage in modified Feekes Scale
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SUMMARY OF OBSERVATIONS ON REFLECTANCE DATA
FOR THE SIX PRODURA WHEAT PLOTS

- A Well Defined Looping Pattern is Present in Smoothed Data.
- Peak Infrared Band Reflectances Occurred Just Prior to Heading, i.e., During Development of the Flag Leaf.
- Reflectances Generally Decreased Proportionally Toward the Origin During Heading and to the Milky-Ripe Stage (11.1).
- Visible Band Reflectances then Increased Substantially Throughout Rest of Ripening Process, with Smaller Decreases in the Infrared.
- Moisture Stress Effects are Evident.
- Lodging Effect is Pronounced.
- Comparable Patterns Exist in Tasseled-Cap-Equivalent Variables.

Cautions Regarding Generalizations:

- Preliminary analysis
- Single variety, grown out of normal geographic region
- Higher planting density than normal for N. Great Plains

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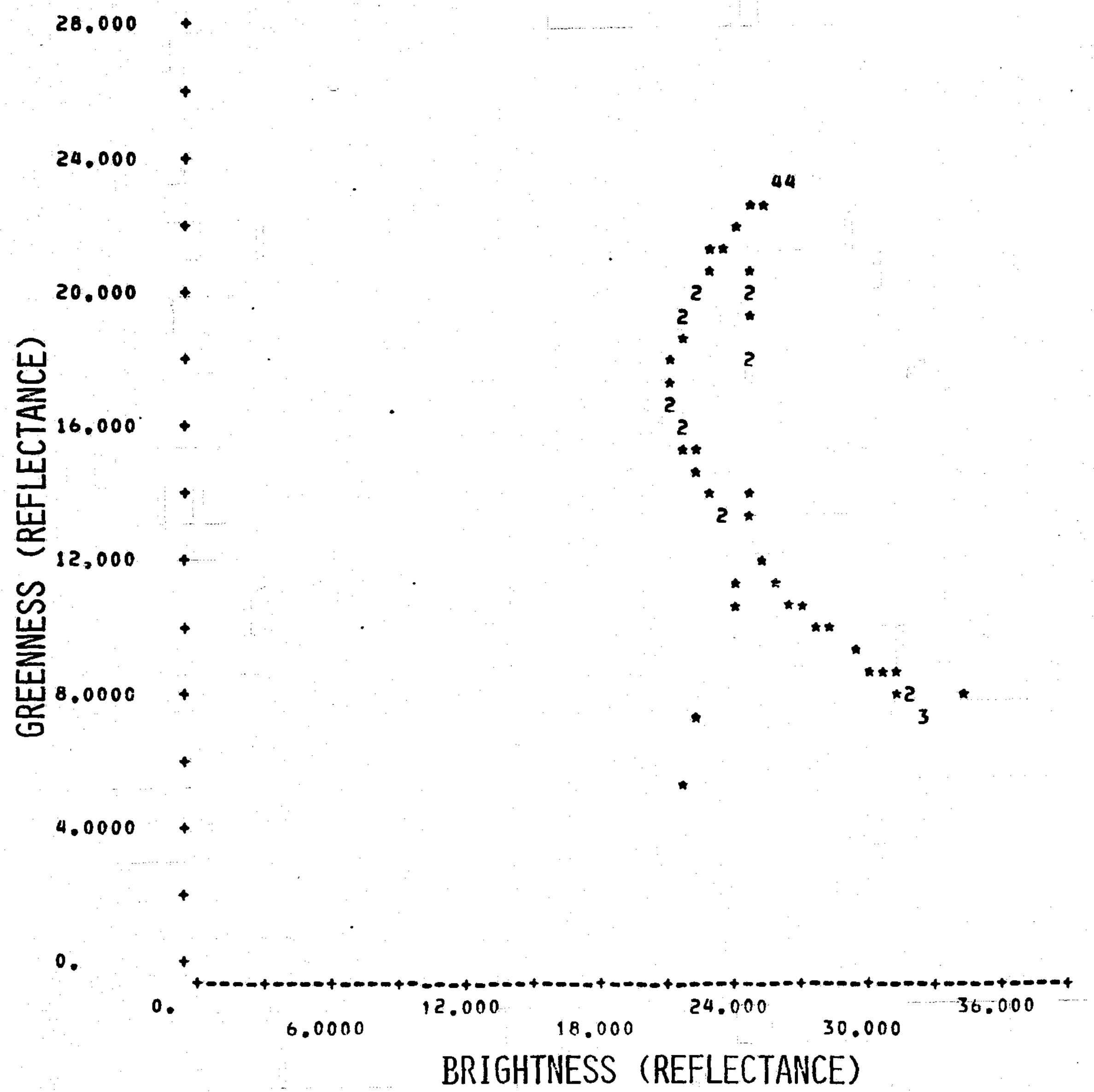
INTERPRETATION OF REFLECTANCE DATA

- PRINCIPAL COMPONENT ANALYSES
  - DEFINED PRINCIPAL PLANE USING ALL DATA
  - DEFINED SOIL LINE USING SOILS DATA
- APPROXIMATED LANDSAT BAND-TO-BAND CALIBRATION RATIOS
- PRODUCED TASSELED-CAP-EQUIVALENT VARIABLES
- COMPUTED TIME PROFILES FOR SEVERAL DIFFERENT GREEN MEASURES
  - SOME COULD DIFFER FROM THOSE OF CORRESPONDING LANDSAT VARIABLES DUE TO EFFECTS OF PATH RADIANCE

TASSELED-CAP-EQUIVALENT SPECTRAL TRAJECTORY
(PLOT 6A, DRY TREATMENT)



CRITERIA FOR SELECTING GREEN MEASURES

- SHAPE OF TIME PROFILE
  - USEFULNESS FOR CROP CALENDAR SHIFT CALCULATIONS
  - EASE OF FITTING MATHEMATICAL FORM
  - EMPHASIS OF PARTICULAR GROWTH STAGES
- STABILITY
  - LOW VARIANCE
  - LACK OF SENSITIVITY TO CERTAIN FACTORS
- CORRELATION WITH AGRONOMIC VARIABLES
- USEFULNESS FOR DISCRIMINATION

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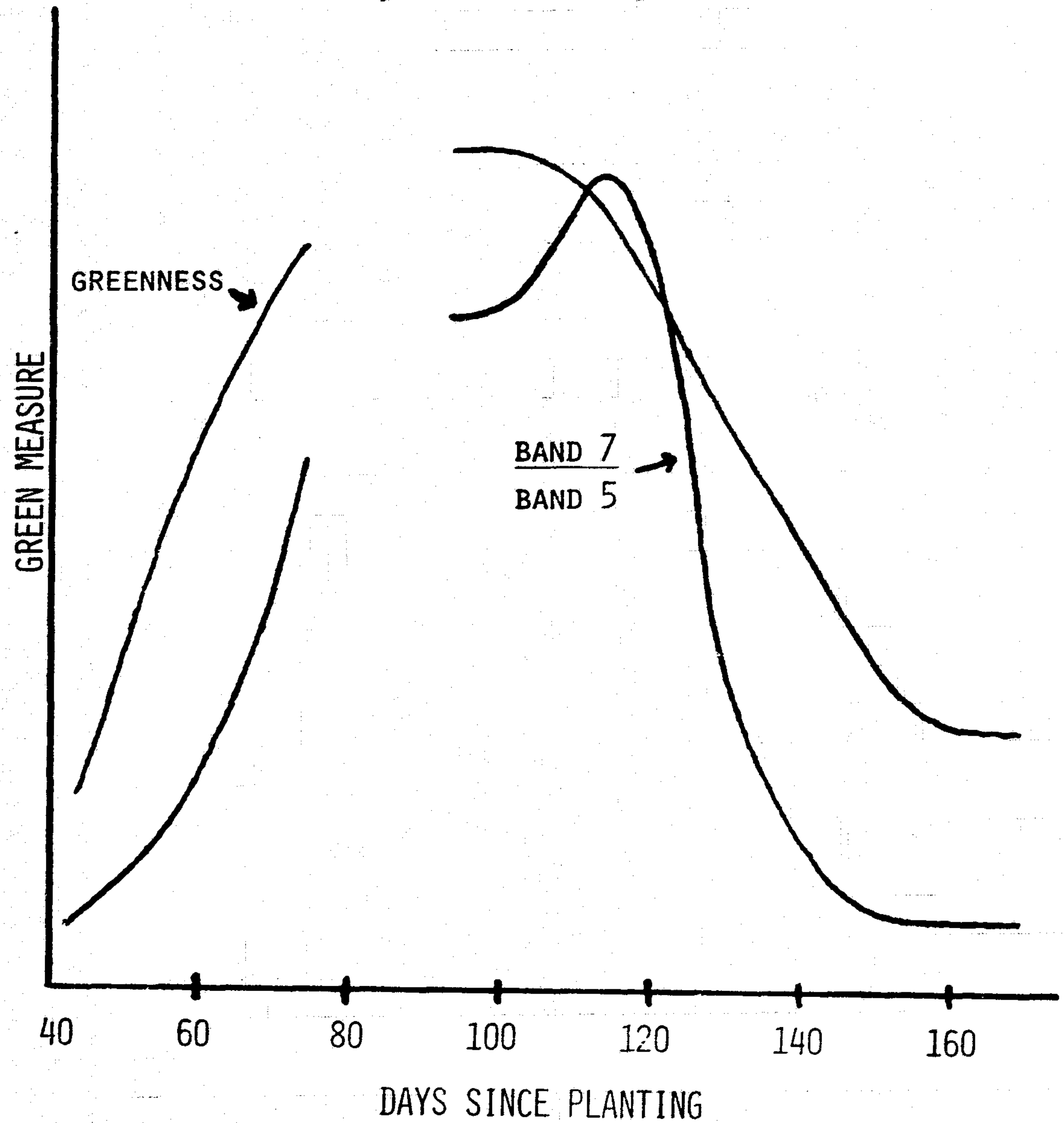
COMPARISON OF GREEN MEASURES:
GREENNESS AND BAND 7/BAND 5
(PLOT 6A, DRY TREATMENT, SMOOTHED DATA)



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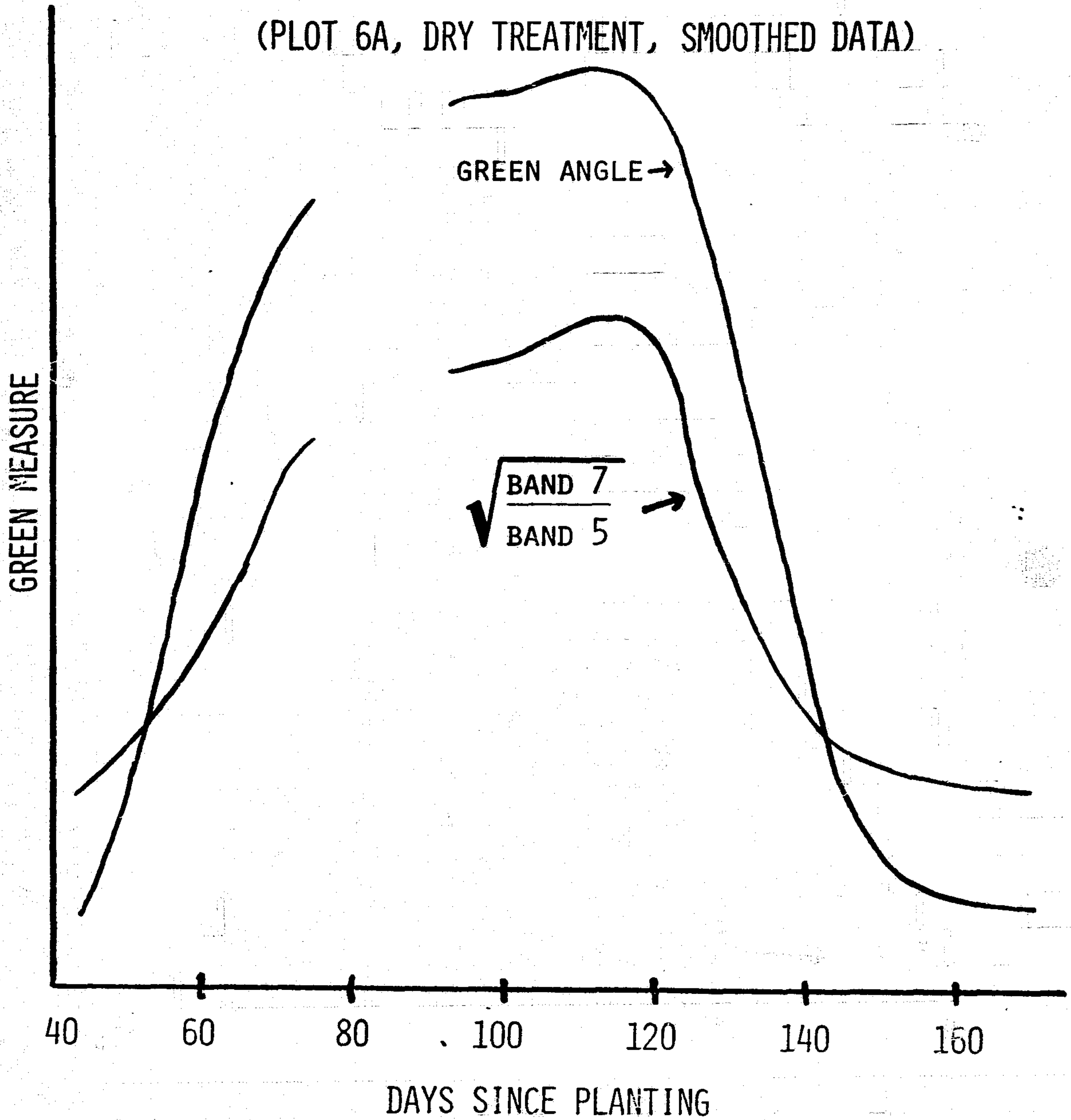
COMPARISON OF GREEN MEASURES (CONTINUED)

$\sqrt{\frac{\text{BAND 7}}{\text{BAND 5}}}$ AND GREEN ANGLE

(PLOT 6A, DRY TREATMENT, SMOOTHED DATA)



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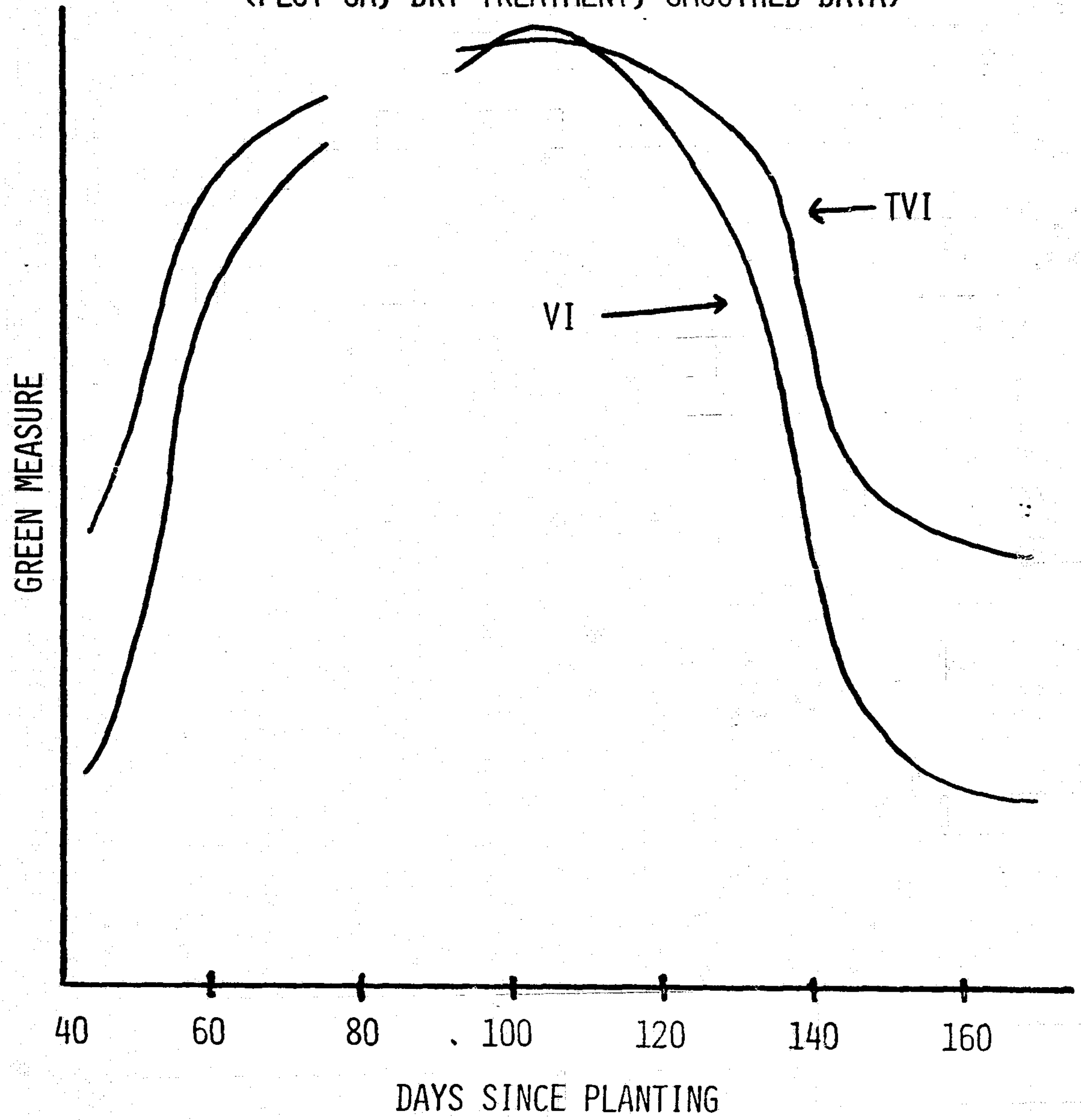
COMPARISON OF GREEN MEASURES (CONTINUED)

VI AND TVI

(PLOT 6A, DRY TREATMENT, SMOOTHED DATA)



STATUS

- Preliminary Analysis of Frequently Measured Wheat Reflectance and Agronomic Data has Clarified or Refined Knowledge of Growth Stage Dependence.
  - Additional analyses planned
  - Additional data needed for generalization
- Insight Gained About Time Profiles of Green Measures
  - No single measure likely to be optimum for all purposes
  - Additional analyses planned
  - Landsat data needed for final characterization and selection
- An Improved Approach for Analyzing and Interpreting Reflectance Data in Terms of Landsat has been Established.
  - Additional discussion in next presentation

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LANDSAT SPACE, REFLECTANCE SPACE, AND THE TASSELED CAP

PETER F. LAMBECK

LANDSAT SPACE, REFLECTANCE SPACE, AND THE TASSELED CAP

OBJECTIVES

- UNDERSTAND THE RELATIONSHIP BETWEEN DATA VALUES AND THEIR FOUR-DIMENSIONAL STRUCTURE IN LANDSAT SPACE AND IN REFLECTANCE SPACE.

- ACQUIRE INSIGHTS ABOUT THE INFORMATION CONTENT OF LANDSAT DATA (AND, POTENTIALLY, THEMATIC MAPPER DATA) PERTAINING TO CROP DEVELOPMENT AND IDENTIFICATION.

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LANDSAT SPACE, REFLECTANCE SPACE, AND THE TASSELED CAP

Approach

- Relate Positions In The Landsat Greenness Vs. Brightness Plane To Various Data Features
  - In-Band Signal Values
  - Band 7 to Band 5 Ratios
  - Other Features
- Examine Similar (Or Equivalent) Relations In Landsat In-Band Reflectance Data
- Improve Estimate Of Transformation From Reflectance Space To XSTAR Corrected Landsat Space
  - Principal Component Method
  - Regression Method Using ITS Field Measurements
    - Improved In-Band Reflectance Calculation
    - Spatially Varying XSTAR Correction

LANDSAT SPACE, REFLECTANCE SPACE, AND THE TASSELED CAP

RECENT PROGRESS

- ANALYSIS OF LANDSAT IN-BAND SIGNAL VALUES AND BAND 7 TO BAND 5 RATIOS RELATIVE TO THE TASSELED CAP HYPERPLANE IS BEING USED TO DEVELOP DATA FEATURES BASED ON A GREEN ANGLE AND A BRIGHTNESS RADIUS.

- LANDSAT IN-BAND REFLECTANCE DATA HAS BEEN FOUND TO HAVE 99+% OF ITS VARIANCE CONFINED TO TWO DIMENSIONS.

- SENESCING VEGETATION HAS NOT BEEN FOUND TO LIE OUTSIDE OF THE REFLECTANCE DATA HYPERPLANE BY ANY SIGNIFICANT AMOUNT.

- A MATHEMATICAL PROCEDURE TO RELATE DIRECTIONS IN REFLECTANCE SPACE TO THE TASSELED CAP AXES, BASED ON AN ANALYSIS OF PRINCIPAL COMPONENTS OF REFLECTANCE DATA, IS BEING TESTED.

- A RIGOROUS REGRESSION PROCEDURE TO RELATE IN-BAND REFLECTANCE MEASUREMENTS TO XSTAR CORRECTED LANDSAT SIGNALS IS PLANNED FOR THE NEAR FUTURE.

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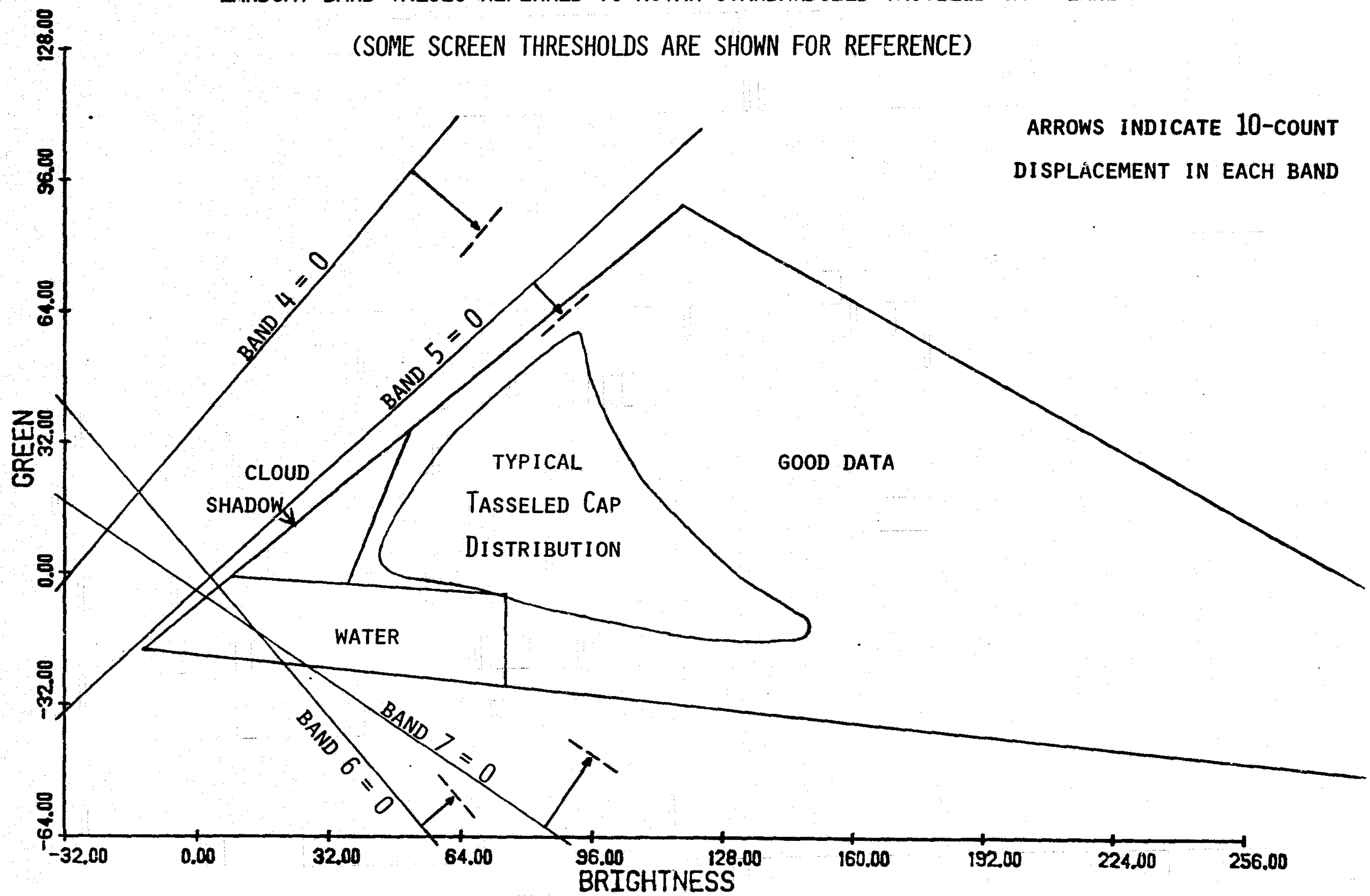
LANDSAT BAND VALUES REFERRED TO XSTAR-STANDARDIZED TASSELED CAP PLANE

(SOME SCREEN THRESHOLDS ARE SHOWN FOR REFERENCE)



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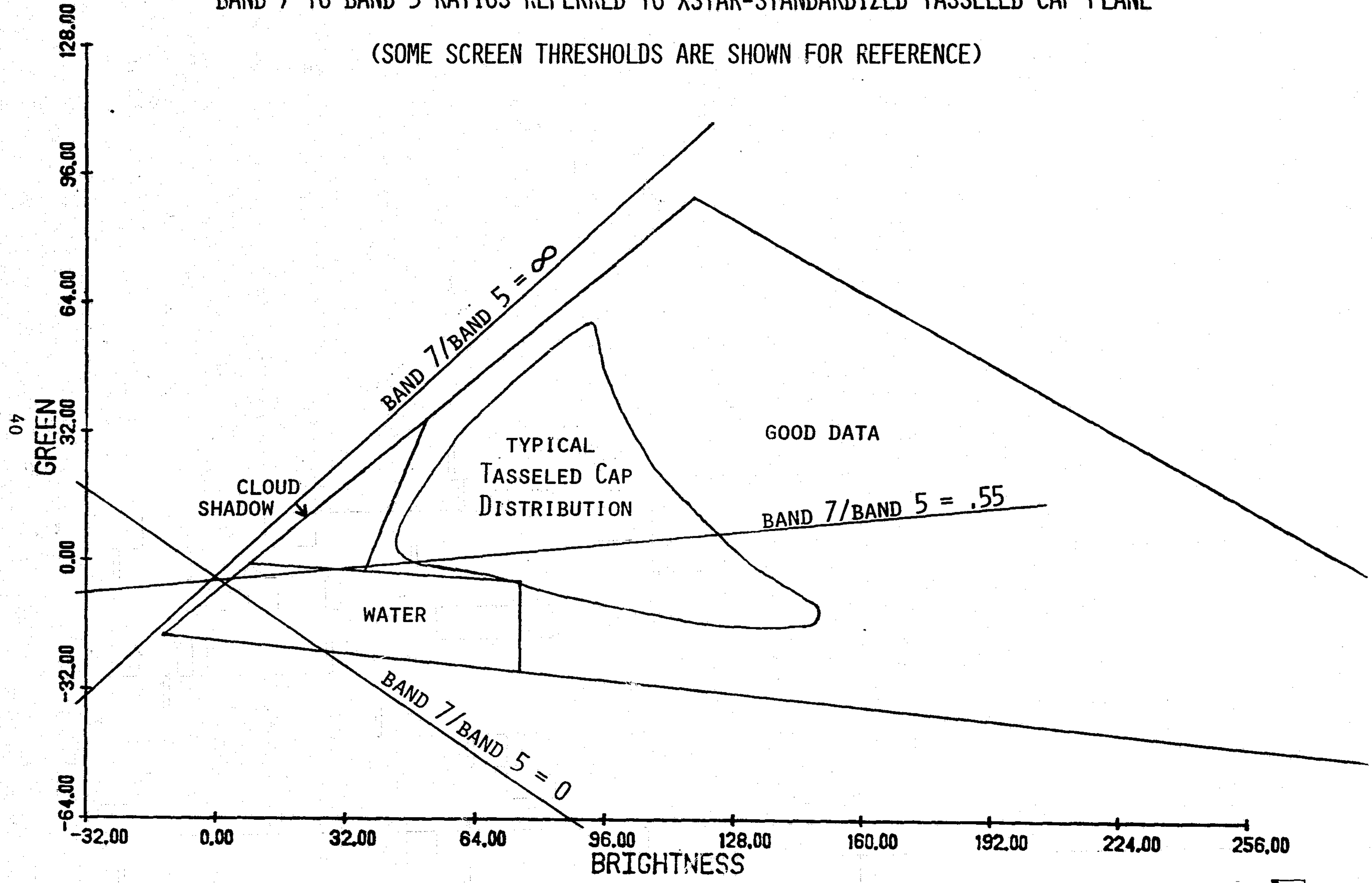
BAND 7 TO BAND 5 RATIOS REFERRED TO XSTAR-STANDARDIZED TASSELED CAP PLANE

(SOME SCREEN THRESHOLDS ARE SHOWN FOR REFERENCE)



SIGNATURE CHARACTERIZATION

OBJECTIVES

- DEVELOP METHODS FOR CHARACTERIZING THE SPECTRAL SIGNATURES OF CROPS, INCLUDING COLLATERAL VARIABLES
- DEVELOP TRANSFORMS THAT WILL REDUCE THE VARIABILITY OR SENSITIVITY OF SIGNATURES TO CHANGED LOCATIONS AND SCENE CONDITIONS
- USE AVAILABLE DATA BASE WITH DEVELOPED METHODS TO SELECT THE MOST DISCRIMINATIVE FEATURES AND TO CHARACTERIZE THE SIGNATURES OF WINTER WHEAT, SPRING WHEAT, AND MAJOR CONFUSION CROPS

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KEY ISSUES FOR SIGNATURE CHARACTERIZATION

- APPLICATION REQUIREMENTS
  - UTILIZE AVAILABLE MULTITEMPORAL ACQUISITION HISTORIES
  - ACCEPT A WIDE RANGE OF OBSERVATION CONDITIONS
  - REPRESENT ACCURATE LIKELIHOOD FUNCTIONS OF CROPS OF INTEREST AND CONFUSION CROPS FOR THE AVAILABLE ACQUISITION HISTORIES AND OBSERVATION CONDITIONS

KEY ISSUES FOR SIGNATURE CHARACTERIZATION (CONTINUED)

- TRAINING REQUIREMENTS
  - UTILIZE AVAILABLE MULTITEMPORAL OBSERVATIONS AND INTERPOLATE TO PROVIDE TIME CONTINUOUS SIGNATURES
  - UTILIZE OBSERVATIONS REPRESENTING A WIDE RANGE OF COLLATERAL CONDITIONS AND INTERPOLATE TO PRODUCE SIGNATURES CONTINUOUS WITH RESPECT TO THESE CONDITIONS
  - UTILIZE A LARGE NUMBER OF RANDOMLY DRAWN OBSERVATION SETS IN ORDER TO ENSURE INCLUSION OF A ROBUST VARIETY OF PATTERNS

SIGNATURE CHARACTERIZATION

APPROACH

- GENERALIZED APPROACH
  - USE GENERALIZED LIKELIHOOD FUNCTION
  - SEEK MULTITEMPORAL, MULTISEGMENT, MULTIMODAL SIGNATURES (FOR WHEAT AND FOR NON-WHEAT)
  - ESTIMATE MISSING DATA USING TEMPORAL DEVELOPMENT PROFILES OR CONDITIONAL EXPECTATION

- TRAJECTORY APPROACH
  - SELECT FEATURES
  - CHARACTERIZE TEMPORAL DEVELOPMENT PROFILES
  - SEEK NORMALIZING RELATIONSHIPS OR TRANSFORMATIONS
  - DEVELOP TRAJECTORY SIGNATURES FOR WHEAT AND FOR THE MAJOR CONFUSION CROPS, AS NEEDED
  - IDENTIFY TIME PERIODS WHICH ARE THE MOST USEFUL FOR CROP DISCRIMINATION

SIGNATURE CHARACTERIZATION

PROGRESS

GENERALIZED SIGNATURE CHARACTERIZATION

- DETERMINED THAT A MULTIMODAL GAUSSIAN CONDITIONAL LIKELIHOOD IS THE PREFERRED CHOICE FOR REPRESENTING SIGNATURES.
- GENERATED AN ALTERNATIVE (CONDITIONAL EXPECTATION) TO BOULLION'S METHOD FOR ESTIMATING SIGNATURE PARAMETERS WHEN THERE ARE MISSING DATA VALUES
- FORMULATED A METHODOLOGY FOR COMBINING THIS WITH CLASSY TO PROVIDE MULTIMODAL SIGNATURES INCORPORATING COLLATERAL VARIABLES.
- BEGAN AN INVESTIGATION OF THE MODIFICATION AND USE OF CLASSY (OR ALL ALTERNATIVE GAUSSIAN CLUSTERING ALGORITHM) TO CARRY OUT THE SIGNATURE ESTIMATION USING A LARGE AMOUNT OF INPUT DATA

LABELING PROCEDURES AND TECHNIQUES

OBJECTIVE

UTILIZE THE UNDERSTANDING AND DISCRIMINATIVE FEATURES DEVELOPED IN FEATURE DEFINITION AND SIGNATURE CHARACTERIZATION TO DEVELOP AND EVALUATE TECHNIQUES AND TOOLS FOR LABELING LANDSAT SCENE FEATURES.

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LABELING PROCEDURES AND TECHNIQUES

Approach

- Analyze and Develop Image Products and Aids
  - Develop understanding of PFC color production system
    - .. Consider psycho-physical characteristics of PFC color space
    - .. Examine alternative colorimetric approaches
  - Develop a color mapping approach to production of image products
    - .. Utilize normalized data
    - .. Employ data-to-color in place of channel-to-primary mapping
    - .. Consider additional color aids and enhanced images
  - Develop Procedure M analyst aids

APPROACH (CONTINUED)

- DEVELOP OBJECTIVE LABELING PROCEDURES
  - FOR WINTER WHEAT AND/OR SPRING SMALL GRAINS
    - .. FOLLOW TWO PARALLEL APPROACHES
      - BUILD ON LIST TECHNOLOGY AND USE OF AIs
      - DEVELOP MACHINE-ONLY OR PREDOMINANTLY MACHINE PROCEDURES
    - .. USE AN ITERATIVE DEVELOPMENT PROCESS FROM CONCEPTUALIZATION THROUGH THE MAJOR ELEMENTS OF THIS TASK AND T&E
  - FOR REFINED MACHINE LABELLER FOR SPRING WHEAT VS. BARLEY
    - .. BASED ON PREVIOUSLY REPORTED T&E RESULTS, IDENTIFY POTENTIAL ERROR SOURCES AND DIAGNOSTICS AND ITERATE THROUGH THE MAJOR ELEMENTS OF THIS TASK
    - .. TO BE DISCUSSED IN DETAIL LATER
- IDENTIFY LABELING ERROR PATTERNS
  - STUDY LACIE AND TRANSITION-YEAR ACCURACY ASSESSMENT RESULTS
  - STUDY TEST AND EVALUATION RESULTS FOR LIST
  - STUDY TEST AND EVALUATION RESULTS FOR PROCEDURE M

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ADVANCED IMAGE PRODUCTS

Progress

- Conducted Evaluation of PFC Color Production Characteristics
  - Evaluated standard LACIE false color image products
  - Applied principles of color science to evaluate PFC characteristics
- Experimental Imagery is Being Prepared:
  - Mapping Tasselled-Cap features into a plane of the L^*, a^*, b^* Uniform Color Space
  - Main differences from our previous examples:
    - •• New plane expands brightness equally with greenness, providing a better brightness resolution than standard image products
    - •• Approximate zero reflectance point is mapped to extrapolated "black" (outside the achievable PFC range)
- Evidence From Preliminary Imagery Indicates That Standardized Data Can Be Portrayed With A Color Mapping That:
  - Is fixed across the growing season
  - Has adequate color resolution
  - Is free of truncation distortion
- Developed Research Versions of Procedure M Analyst Aids

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REFINEMENT OF A MACHINE

TECHNIQUE FOR DISTINGUISHING SPRING WHEAT

FROM OTHER SPRING SMALL GRAINS

ERIC P. CRIST

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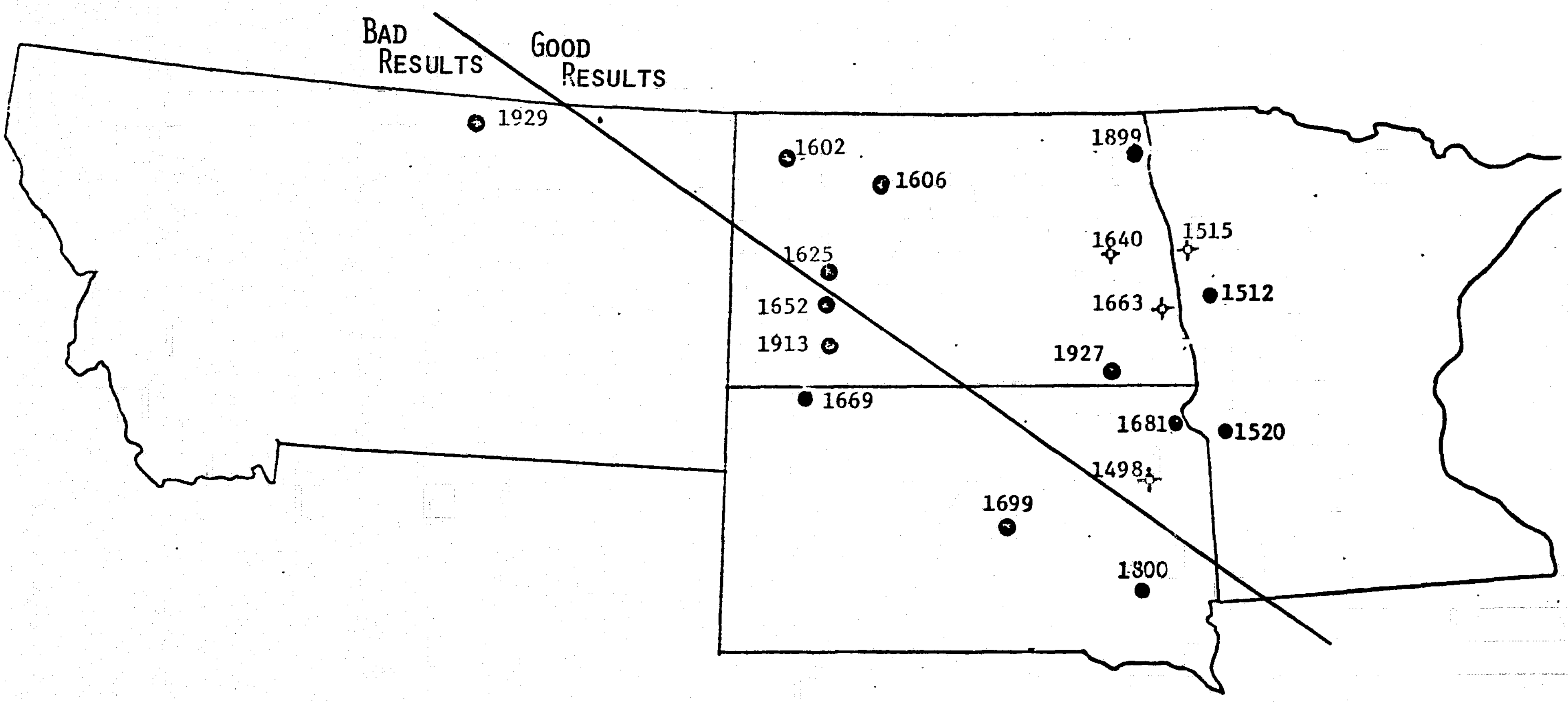
TEST RESULTS -- DEC. 1978



Training Site

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OBJECTIVES OF REVISION EFFORT

- Increase the Geographic Range of Effectiveness of the Spring Wheat/Other Small Grains Labeler
- Arrive at Results in Landsat Space That are Correlated to Observable Phenomena on the Ground

PROGRESS

- Modified Crop Calendar Shift Procedure to Estimate and Use Segment Specific Profile
- Identified Spectral Effects, in Reflectance and Landsat Space, of Moisture Stress and Soil Brightness
- Formulated Mechanism for Adaptation of Labeler to Moisture Stress and Soil Brightness Effects

TECHNICAL BACKGROUND

- PRELIMINARY STEPS
  - DISTINGUISH SPRING SMALL GRAINS FROM OTHER CROPS
  - SCREEN SEGMENTS FOR ADEQUATE ACQUISITIONS

- ORIGINAL LABELING PROCEDURE
  - ESTIMATE CROP CALENDAR SHIFT
  - ASSIGN LABEL BASED ON A CHARACTERISTIC DISTANCE IN TASSELLED-CAP BRIGHTNESS-GREENNESS SPACE

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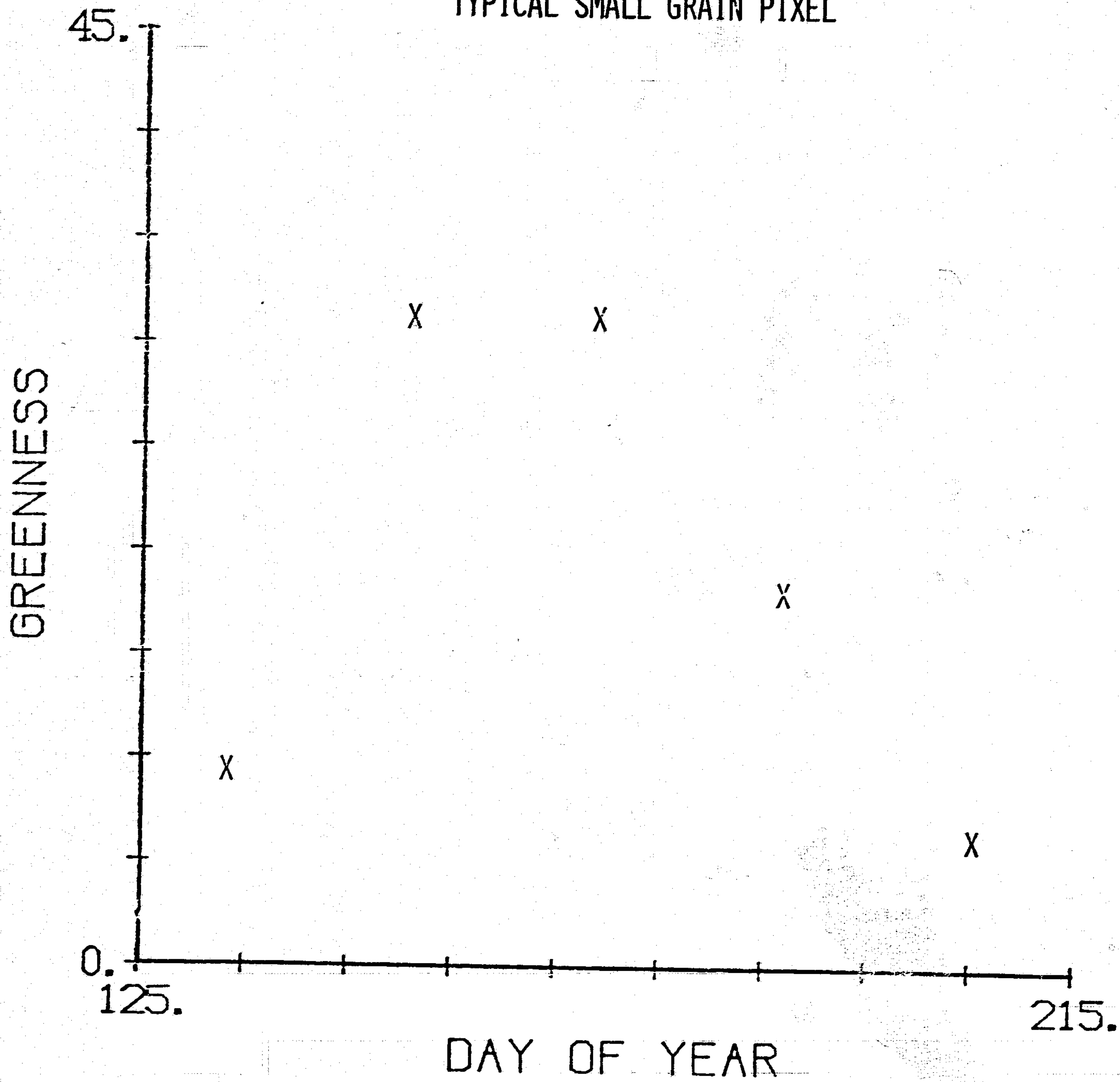
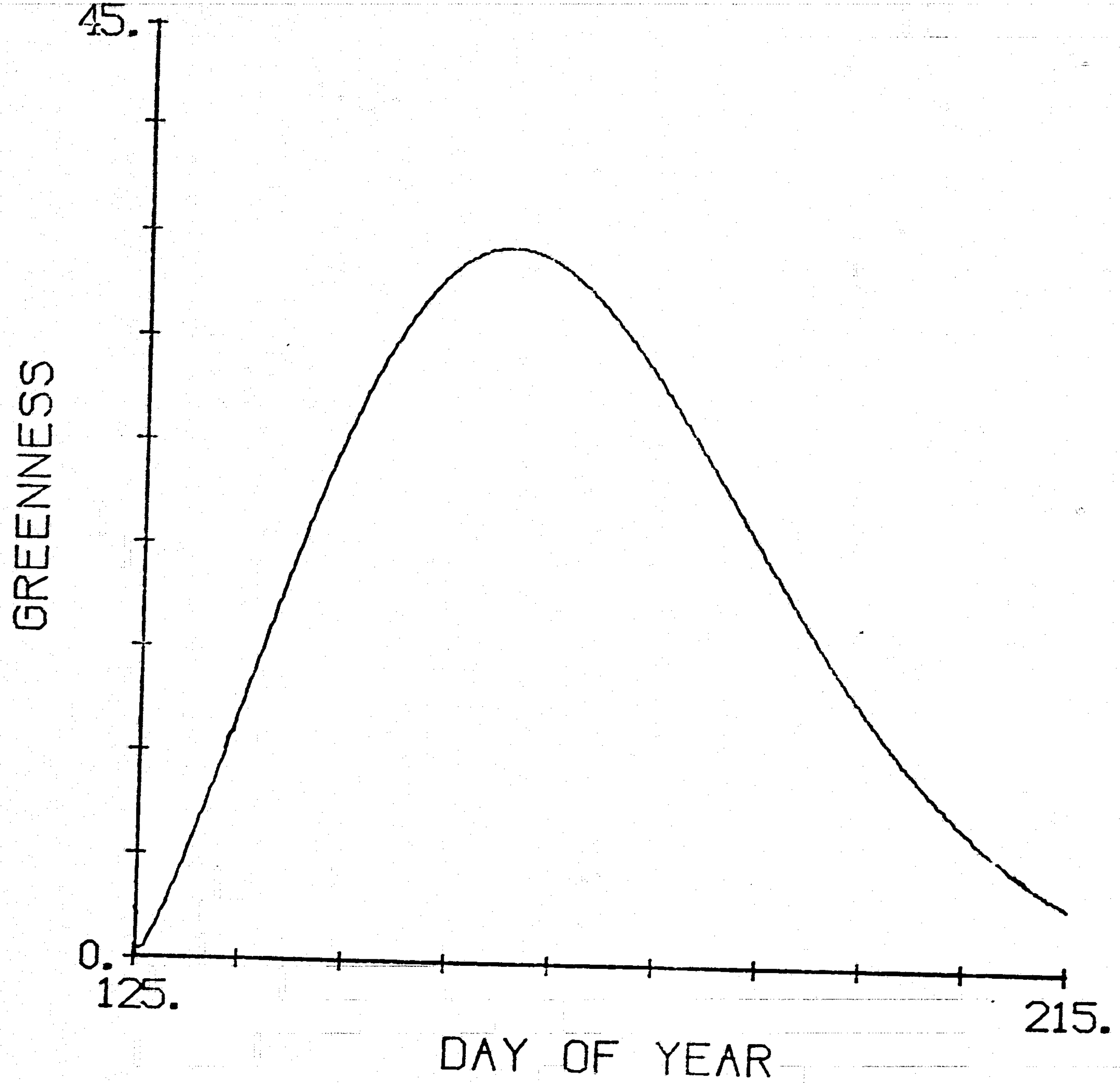
TYPICAL SMALL GRAIN PIXEL





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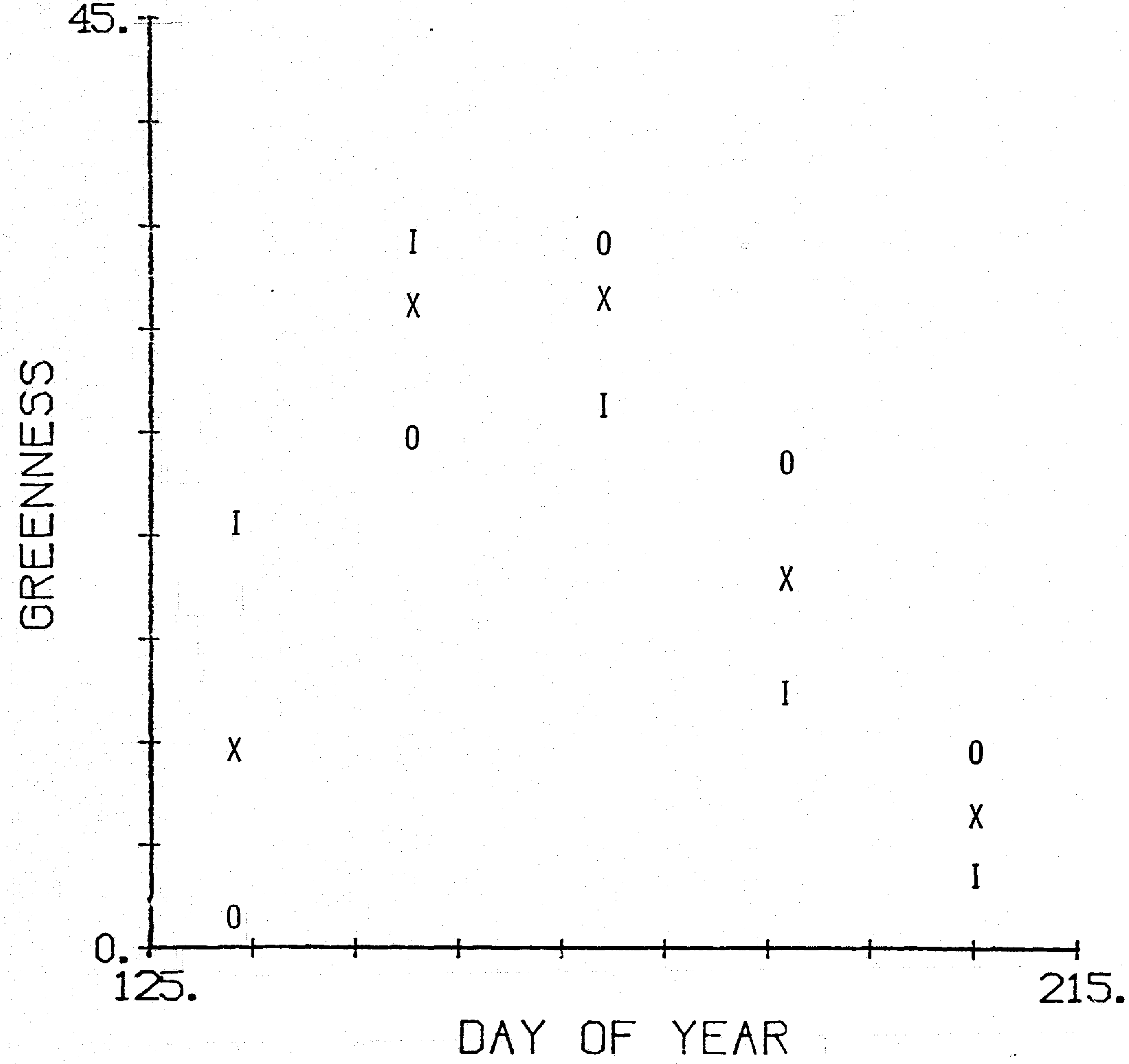
TYPICAL SET OF SMALL GRAIN PIXELS



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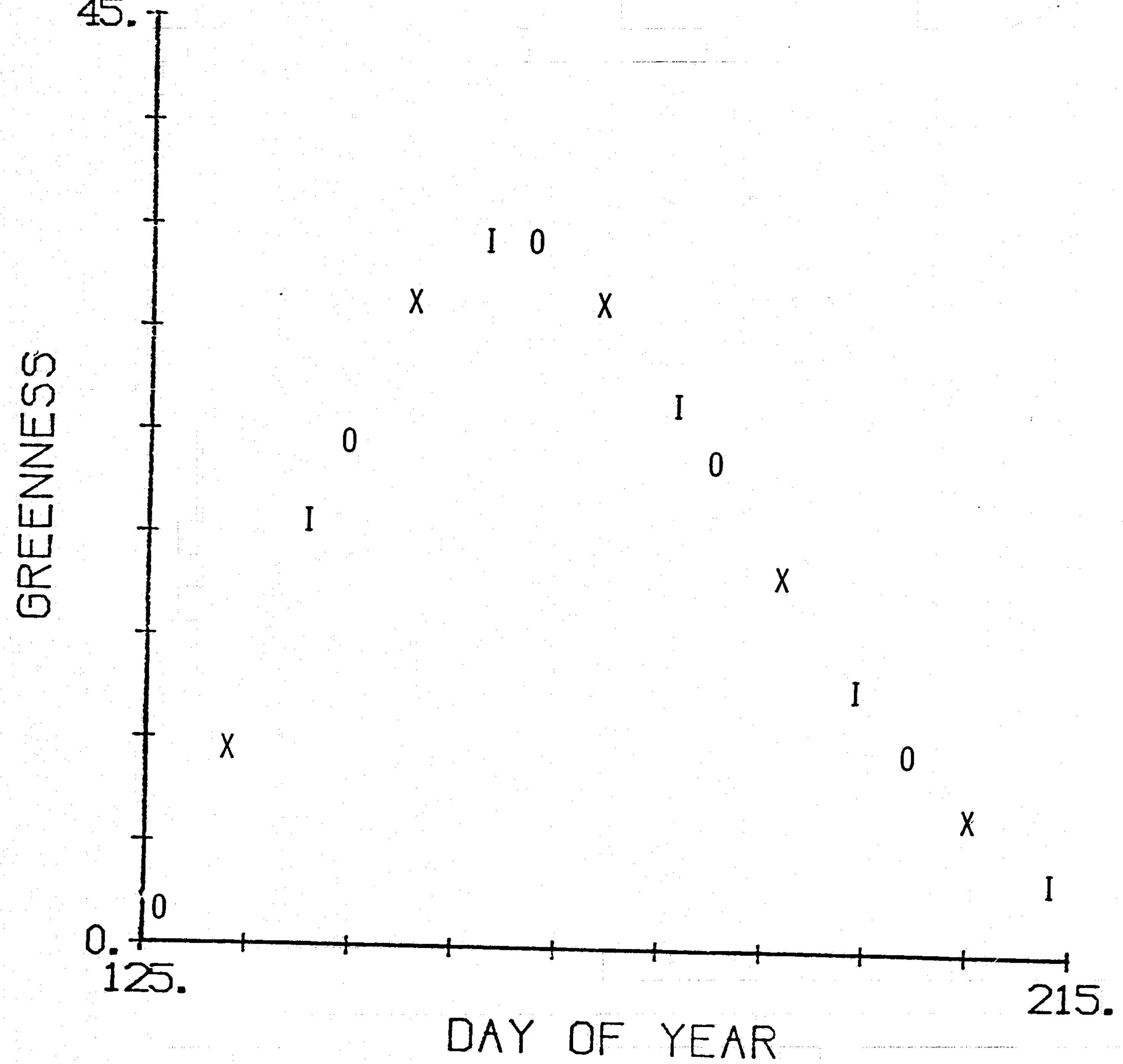
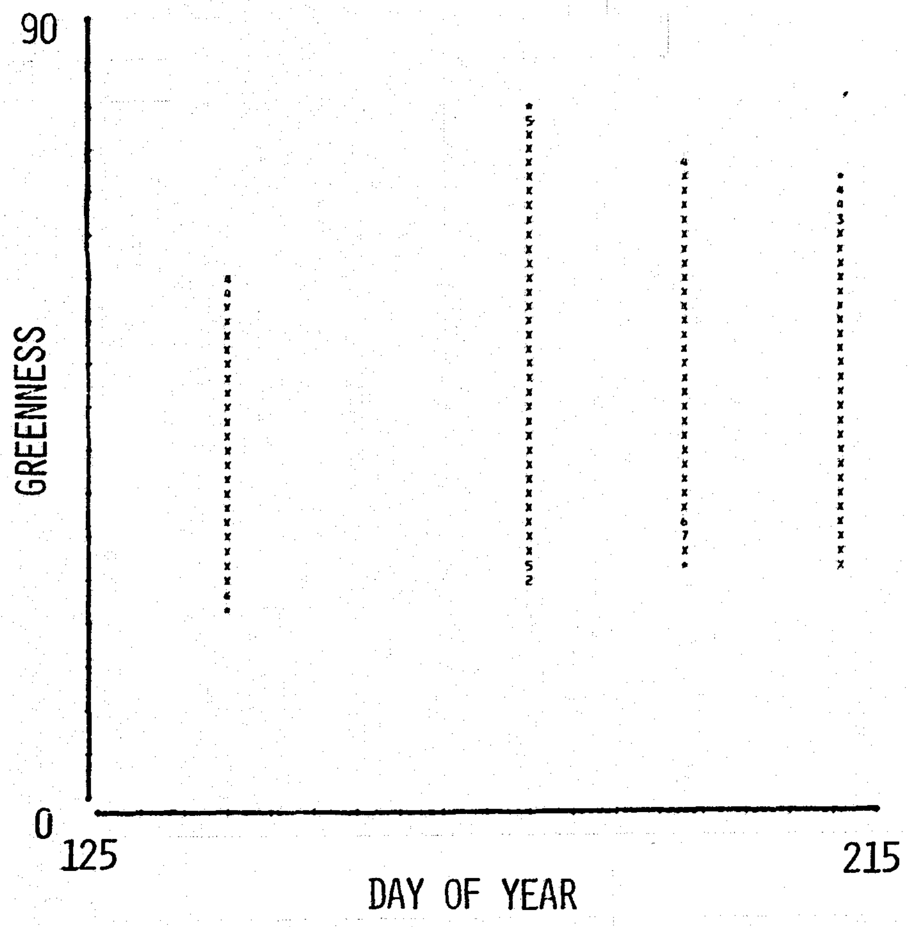
SET OF SMALL GRAIN PIXELS AFTER SHIFT

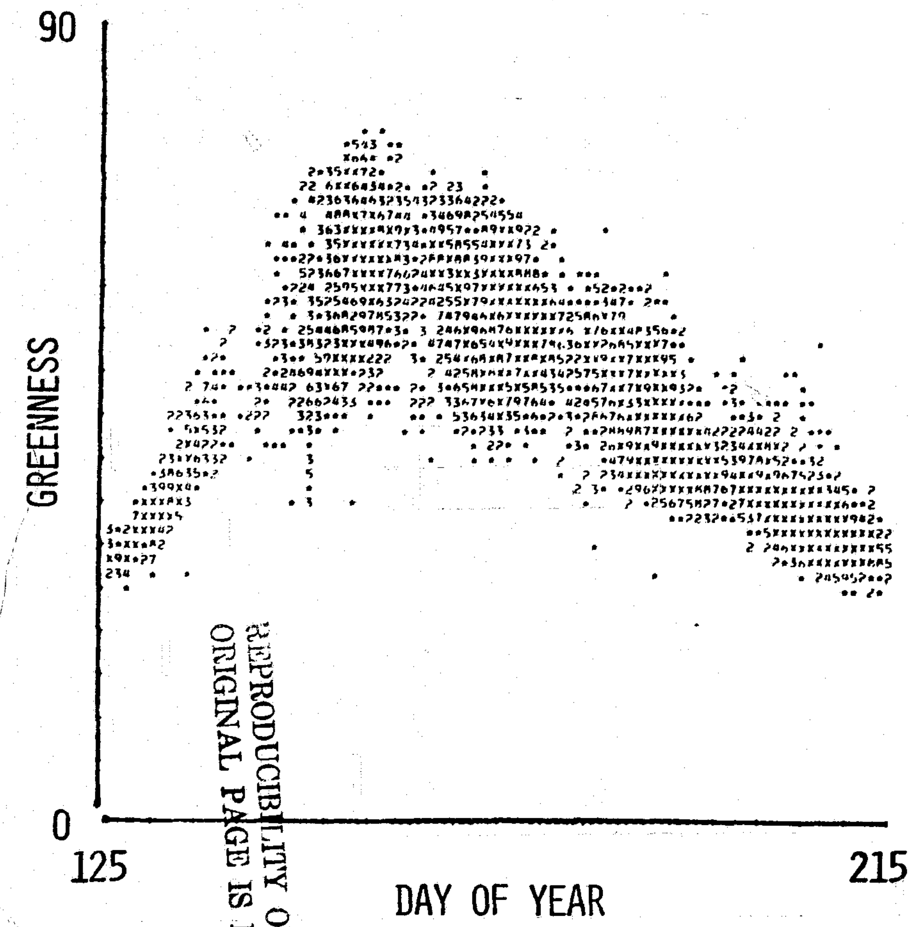


EXAMPLE OF CROP CALENDAR SHIFT ESTIMATION -- LANDSAT DATA

No Shift



Shift With
Reference Profile



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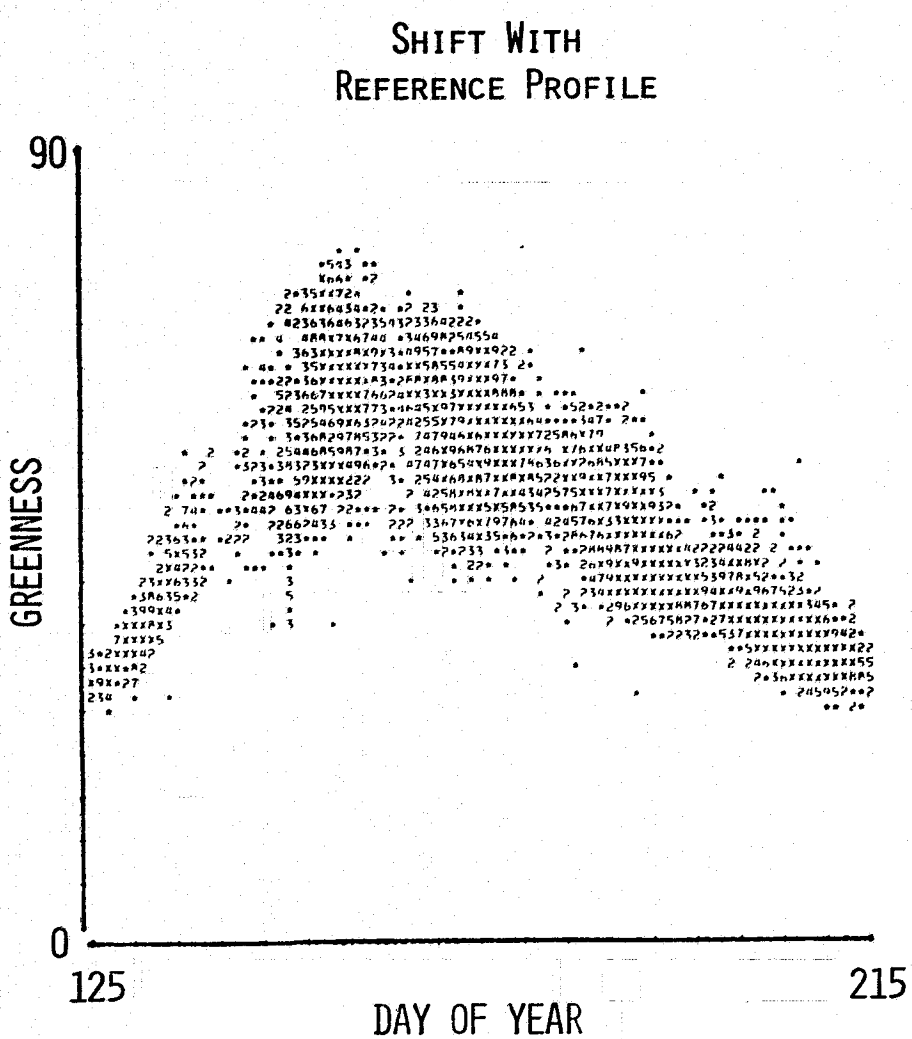
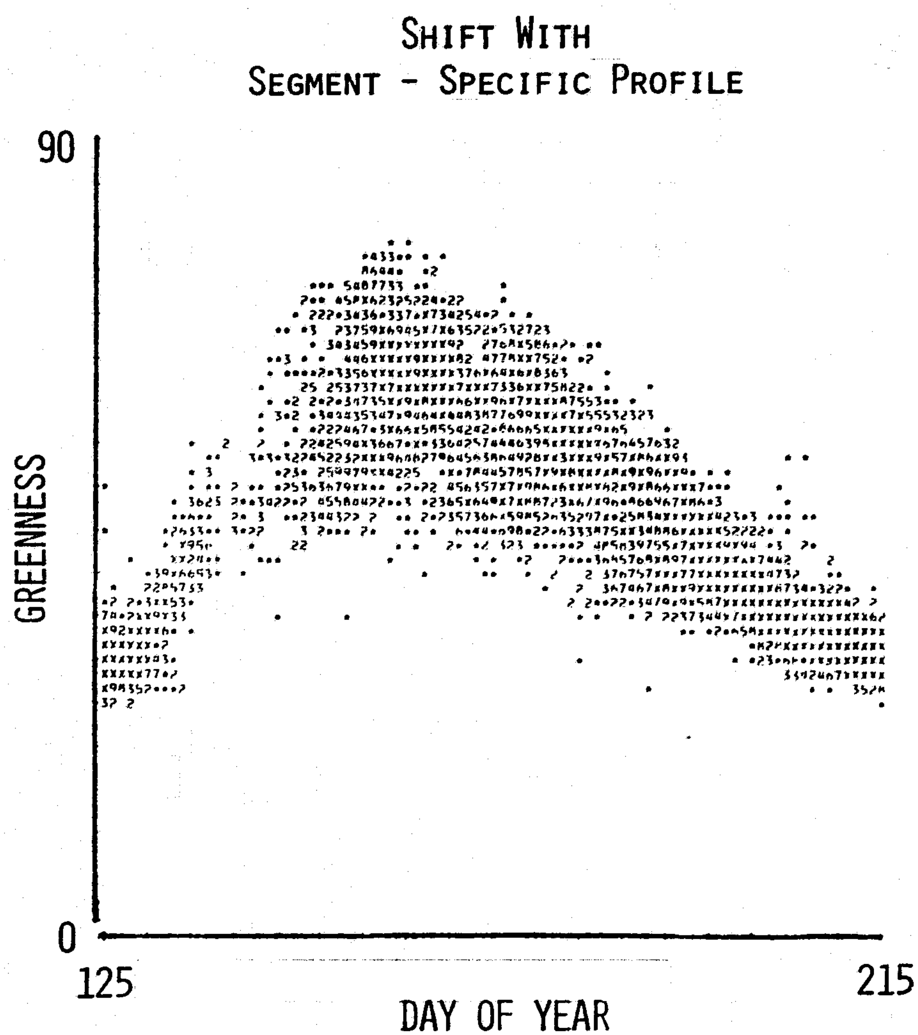
EXAMPLE OF CROP CALENDAR SHIFT

(CONTINUED)





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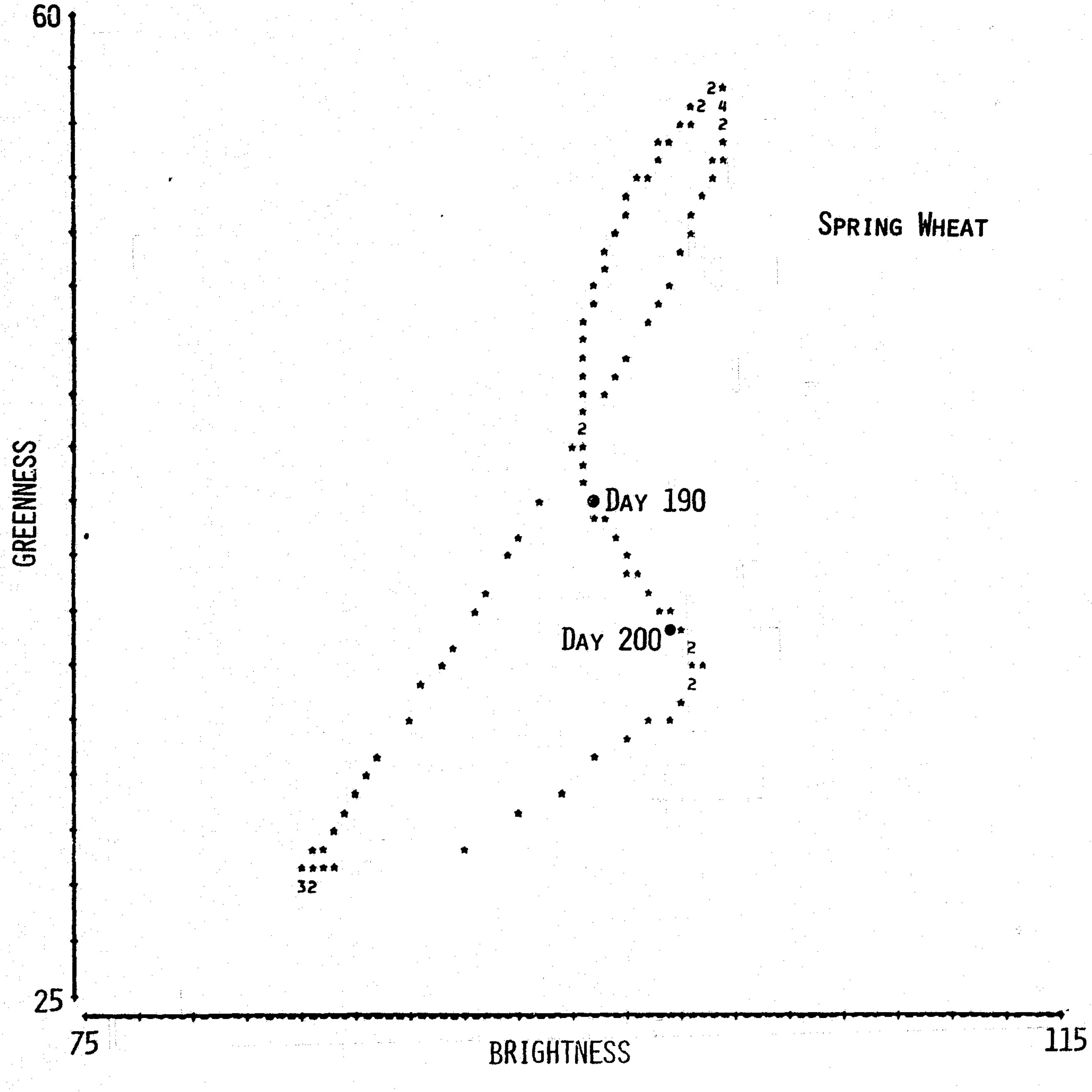
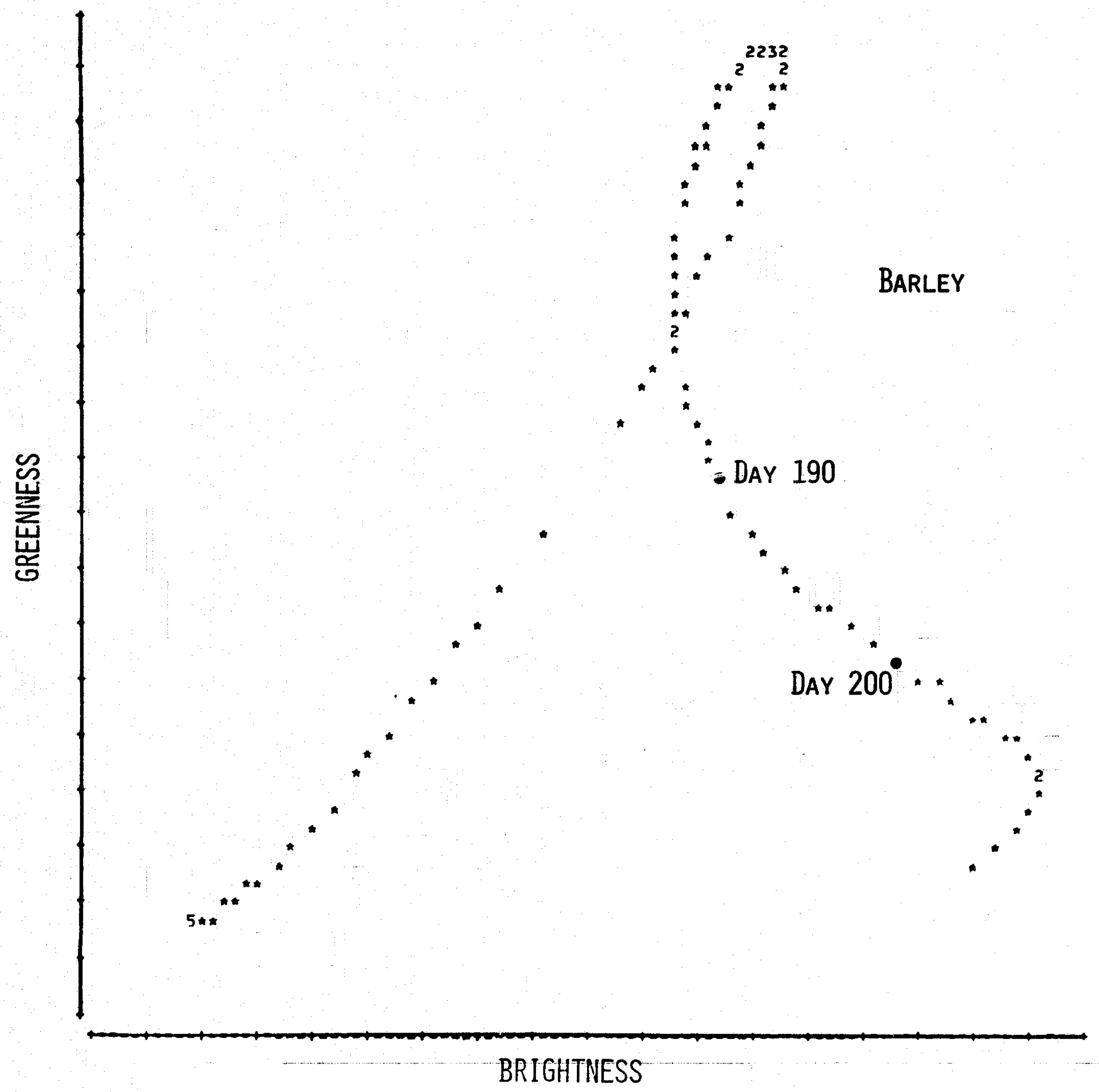
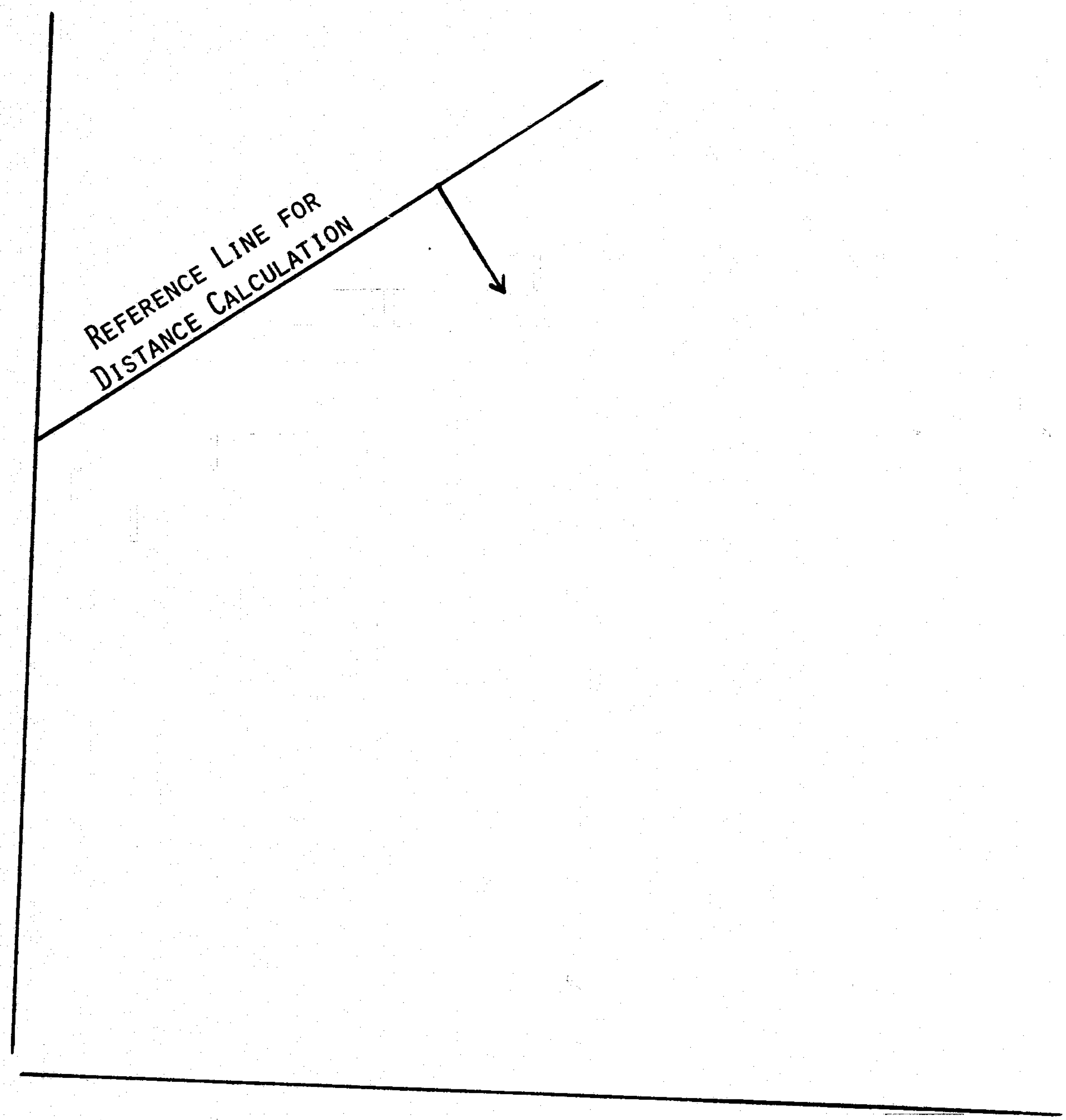
SMOOTHED CURVE OF MEANS




BARLEY
DAY 190
DAY 200
GREENNESS
BRIGHTNESS


REFERENCE LINE FOR
DISTANCE CALCULATION

APPROACH

- DEVELOP HYPOTHESES
- IDENTIFY PERTINENT PHYSIOLOGICAL RELATIONSHIPS, EFFECTS
- MODEL CANOPY REFLECTANCE
- ANALYZE FIELD MEASUREMENTS DATA
- ANALYZE LANDSAT DATA

1. DEVELOP HYPOTHESES

PURPOSE: PROVIDE INITIAL FOCUS AND DIRECTION FOR RESEARCH PROCESS

PRELIMINARY HYPOTHESIS

- DISTINCT GEOGRAPHIC SEPARATION OF "GOOD" AND "BAD" RESULTS SUGGESTS CROP SIGNATURE VARIATIONS CAUSED BY
  - MOISTURE STRESS
  - VARIATIONS IN SOIL BRIGHTNESS

2. IDENTIFY PERTINENT PHYSIOLOGICAL RELATIONSHIPS, EFFECTS

PURPOSE: IDENTIFY CROP RESPONSES TO A GIVEN CONDITION (E.G., MOISTURE STRESS), WITH PARTICULAR ATTENTION TO THOSE RESPONSES LIKELY TO INFLUENCE THE CROP SIGNATURE

PHYSIOLOGICAL EFFECTS OF MOISTURE STRESS

- IMPACT OF INADEQUATE MOISTURE VARIES SIGNIFICANTLY WITH
  - STAGE OF CROP DEVELOPMENT AT INITIATION OF STRESS
  - DURATION OF STRESS
- EFFECTS OF PROLONGED MOISTURE STRESS INCLUDE
  - REDUCED PLANT HEIGHT
  - REDUCED NUMBER OF TILLERS PER PLANT
  - THINNER, SMALLER LEAVES
  - LEAF ROLLING, WILTING
  - REDUCED STAND DENSITY
  - INCREASED DEVELOPMENT RATE

3. MODEL CANOPY REFLECTANCE

PURPOSE: UNDERSTAND THE LIKELY EFFECTS OF RELEVANT PHYSIOLOGICAL CHANGES ON CROP REFLECTANCE

CANOPY MODELING

- THREE SOIL BRIGHTNESSES

- TWO CANOPIES (INTERVALS FROM EMERGENCE TO HARVEST)

  - "NORMAL" PARAMETERS DERIVED FROM FIELD MEASUREMENTS
  - "STRESSED" MODIFICATION OF NORMAL PARAMETERS TO SIMULATE EFFECTS OF PROLONGED MOISTURE STRESS

- RESULTS ARE QUALITATIVE, I.E., SHOW TRENDS RATHER THAN ABSOLUTE NUMBERS

  - INPUTS ARE ESTIMATED
  - GREENNESS AND BRIGHTNESS ARE DERIVED FROM PRINCIPAL COMPONENTS IN REFLECTANCE SPACE -- NOT PERFECT MATCH TO LANDSAT TASSELED CAP

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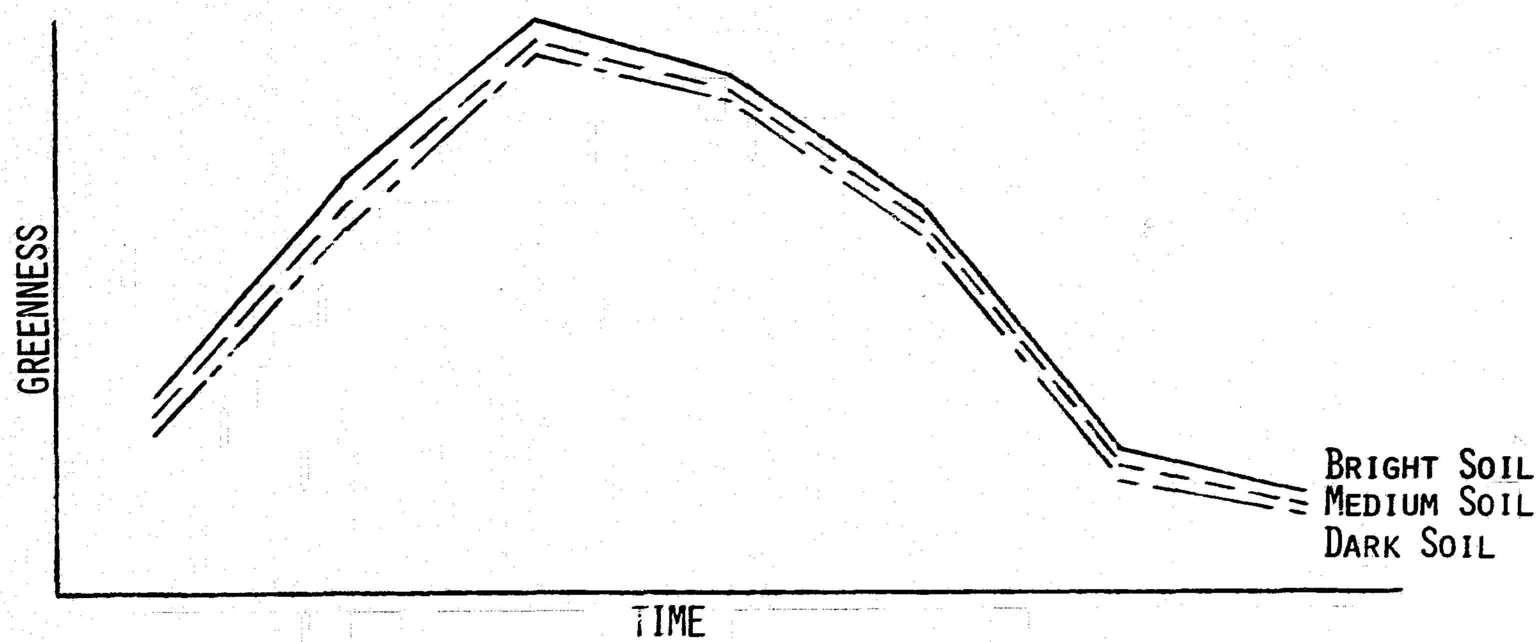
CANOPY MODELING RESULTS

SOIL BRIGHTNESS EFFECTS - NORMAL CANOPY

- GREENNESS - NO SIGNIFICANT IMPACT



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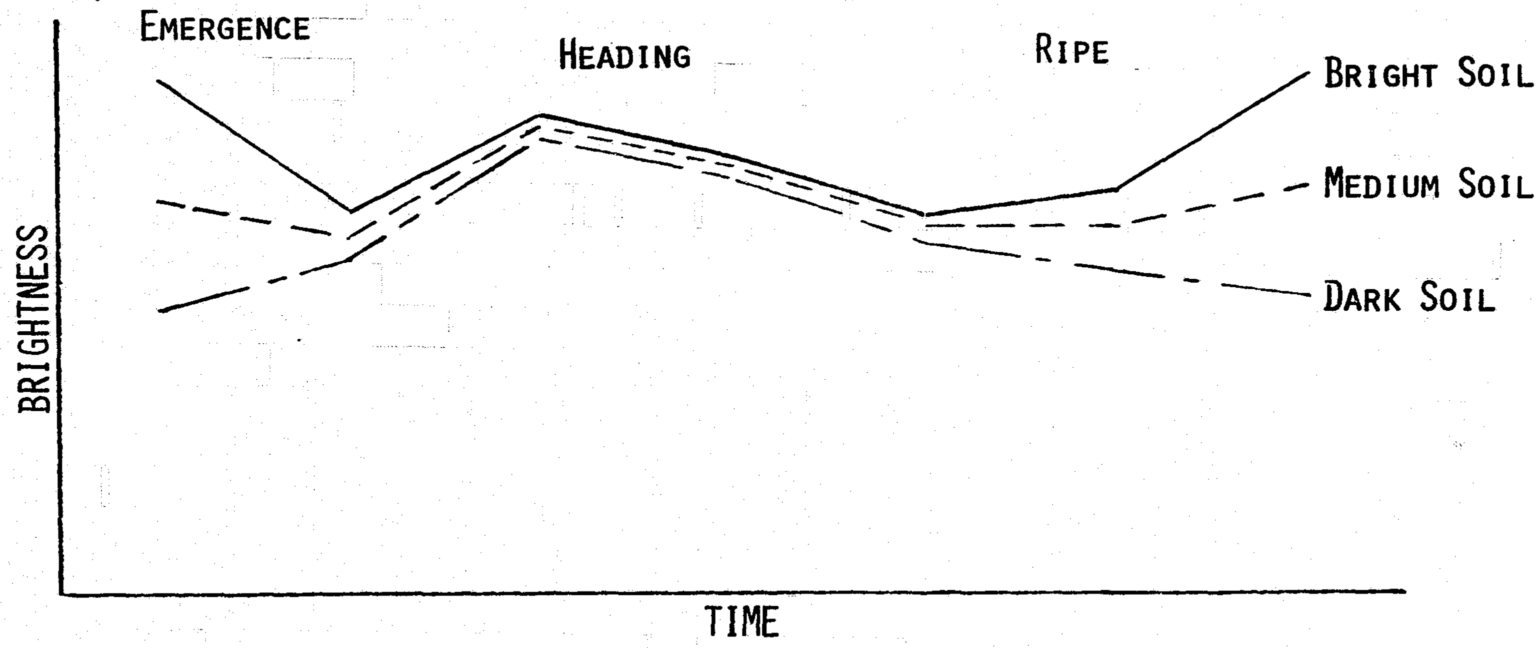
CANOPY MODELING RESULTS

SOIL BRIGHTNESS EFFECTS - NORMAL CANOPY

(CONTINUED)

- BRIGHTNESS - SIGNIFICANT IMPACT IN TAILS OF PROFILE WHERE CANOPY IS MOST OPEN

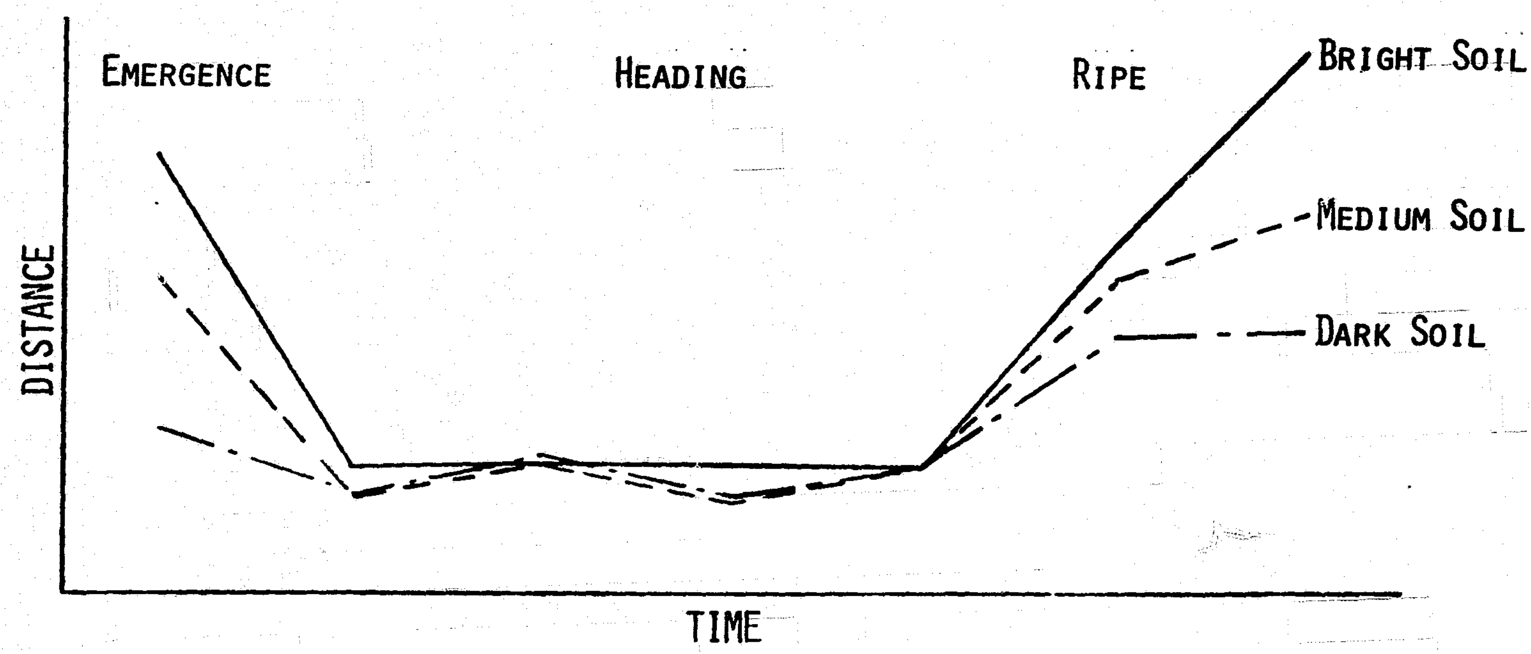


CANOPY MODELING RESULTS

SOIL BRIGHTNESS EFFECTS - NORMAL CANOPY

(CONTINUED)

- DISTANCE - INCREASE IN SLOPE AT TAILS WHERE CANOPY CLOSURE IS CHANGING



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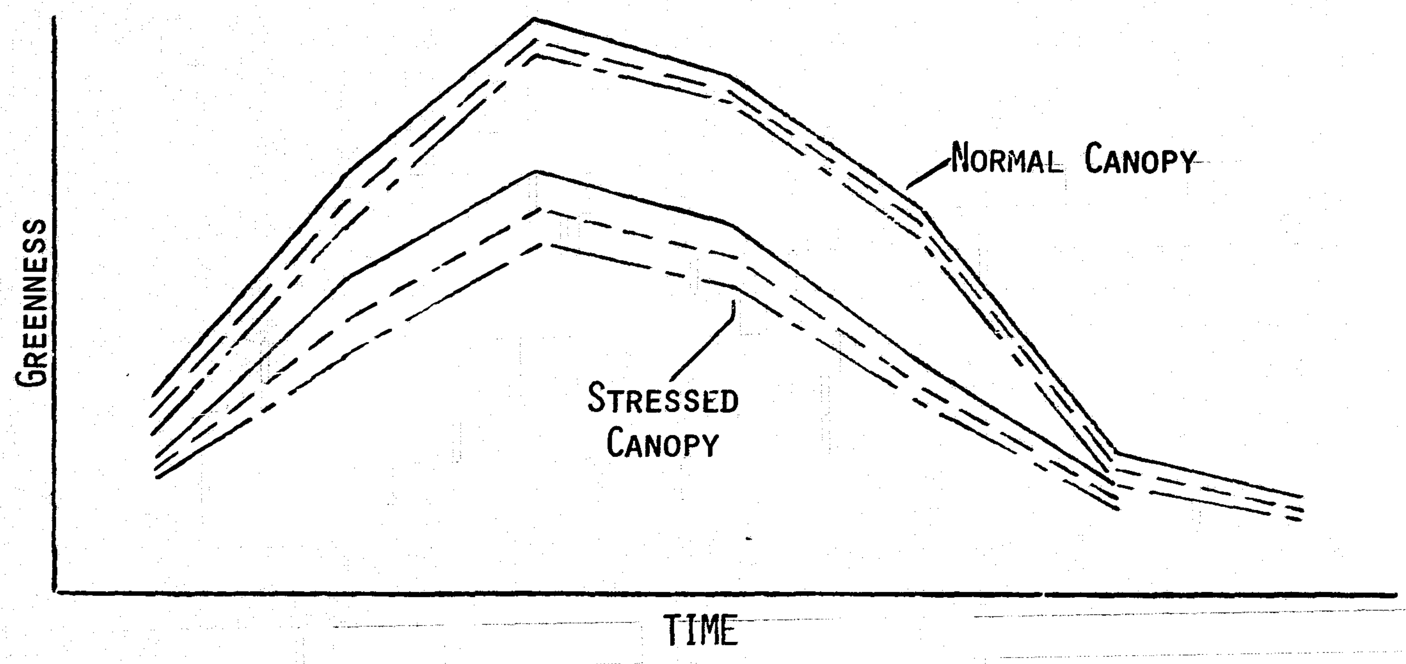
CANOPY MODELING RESULTS

MOISTURE STRESS EFFECTS

- GREENNESS - SIGNIFICANT DECREASE IN PROFILE PEAK



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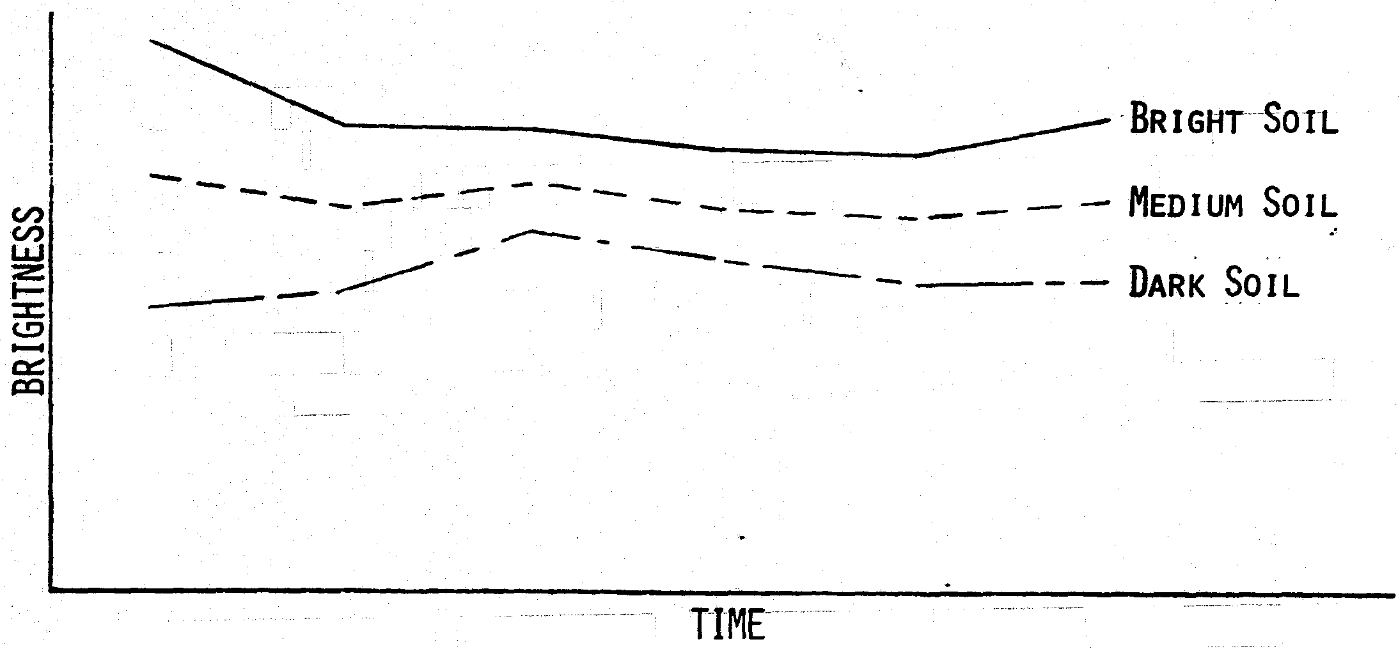
CANOPY MODELING RESULTS
MOISTURE STRESS EFFECTS
(CONTINUED)

- BRIGHTNESS - VARIABLE IMPACT - ENHANCES SOIL BRIGHTNESS EFFECTS



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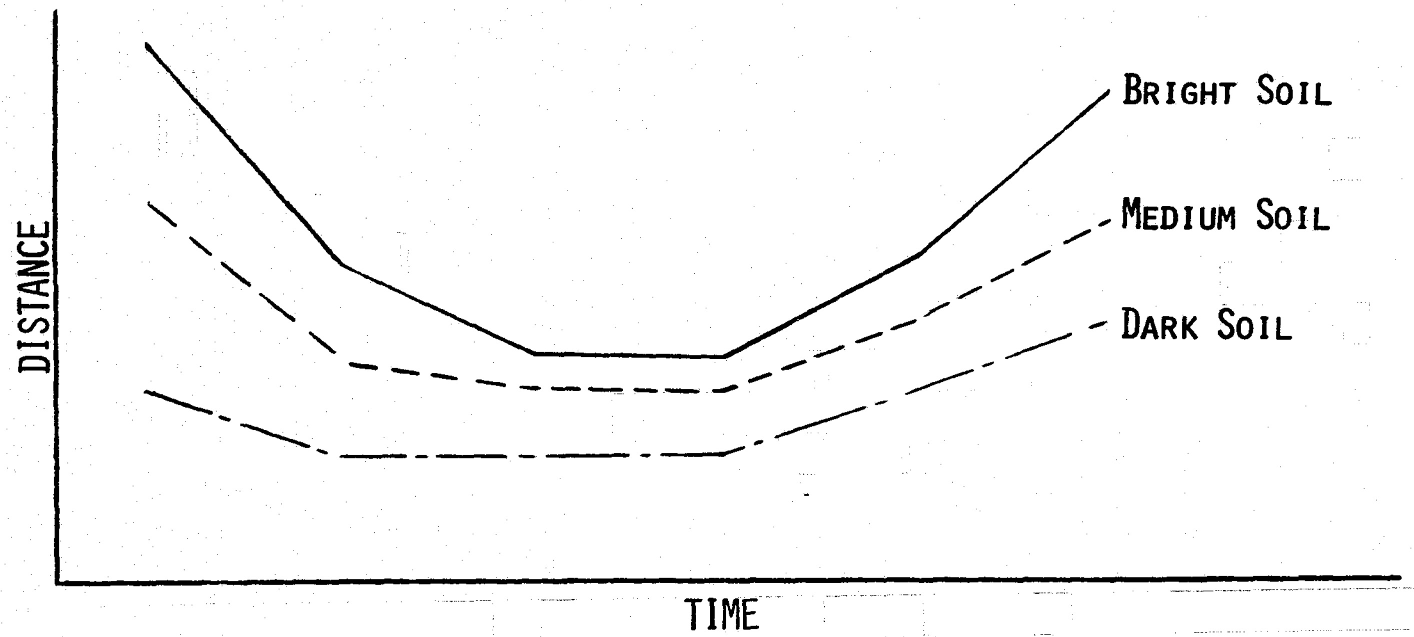
CANOPY MODELING RESULTS
MOISTURE STRESS EFFECTS
(CONTINUED)

- DISTANCE
  - OVERALL INCREASE
  - ELIMINATION OF CONSTANT-VALUE CENTER PORTION



CANOPY MODELING RESULTS

SUMMARY

- SOIL BRIGHTNESS EFFECTS
  - GREENNESS - NONE
  - BRIGHTNESS - TAILS OF PROFILE
  - DISTANCE - INCREASED SLOPE IN TAILS OF PROFILE

- MOISTURE STRESS EFFECTS
  - GREENNESS - REDUCED PEAK
  - BRIGHTNESS - ENHANCED SOIL BRIGHTNESS EFFECTS
  - DISTANCE - OVERALL INCREASE, EARLIER DEPARTURE FROM MINIMUM

4. ANALYZE FIELD MEASUREMENTS DATA

PURPOSE: PROVIDE CANOPY MODEL/REAL WORLD AND GROUND/SATELLITE LINKS, OBSERVE RANGES OF NATURAL VARIABILITY

FIELD MEASUREMENTS

- PRIMARY USES IN THIS EFFORT
  - CONFIRMED RESULTS OF PHYSIOLOGICAL EFFECTS STUDY
  - SUPPORTED CANOPY MODELING WORK
    - DROVE INPUTS
    - PROVIDED CONTEXT FOR CHECKING RESULTS
  - COMBINED WITH FIELD EXPERIENCE, PROVIDED DIRECT LINK TO GROUND PHENOMENA

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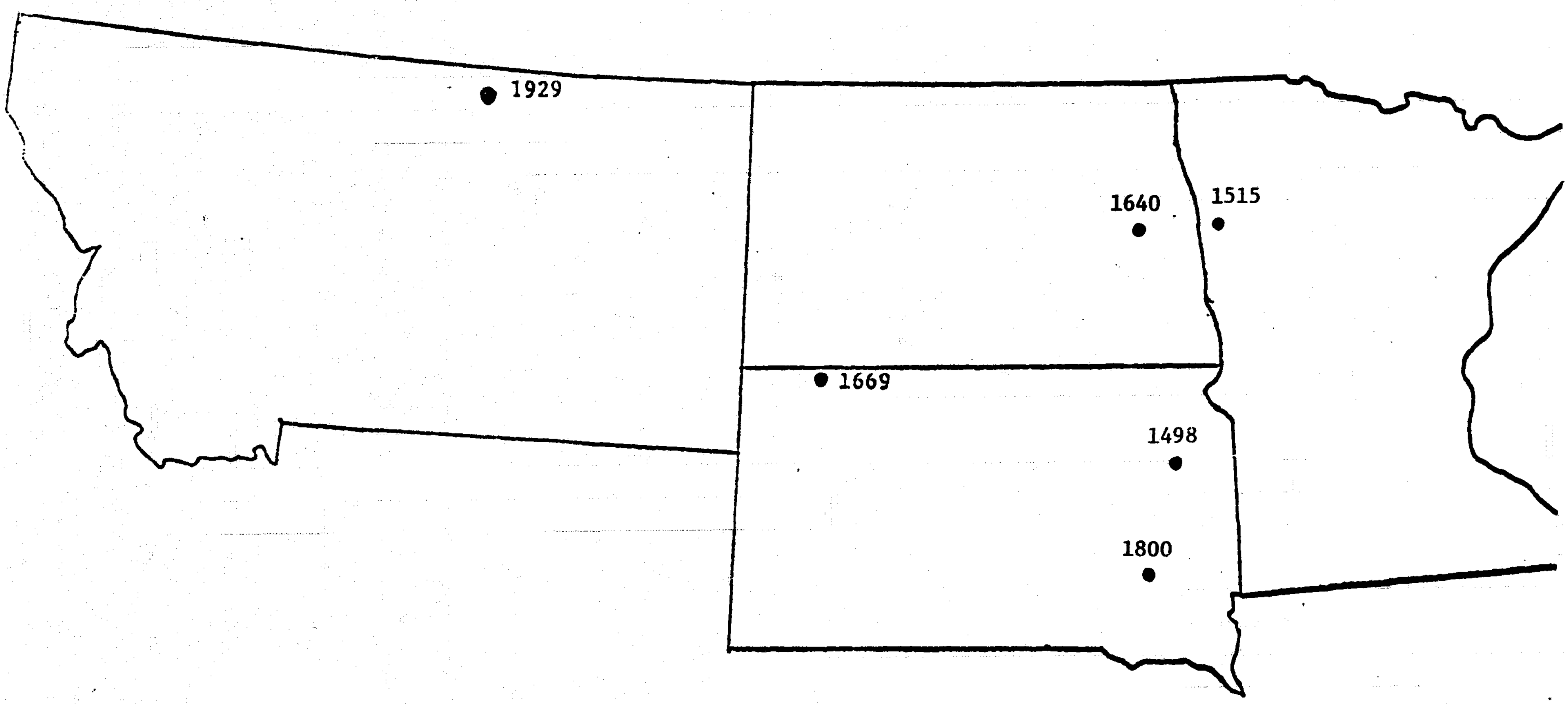
5. ANALYZE LANDSAT DATA

PURPOSE: Assess Utility of Spectral Relationships Observed in Model and Field Data, Derive Viable Procedure for Their Use

LANDSAT DATA ANALYSIS

SEGMENTS USED



LANDSAT DATA ANALYSIS

MODEL AND FIELD RESULTS SUGGEST THE FOLLOWING RELATIONSHIPS:

PHENOMENON	SPECTRAL DETECTION MECHANISM	EFFECT ON DISTANCE DECISION LINE
MOISTURE STRESS	GREEN PEAK	EARLIER TIME PERIOD
BRIGHT SOIL	EARLY BRIGHTNESS	STEEPER SLOPE

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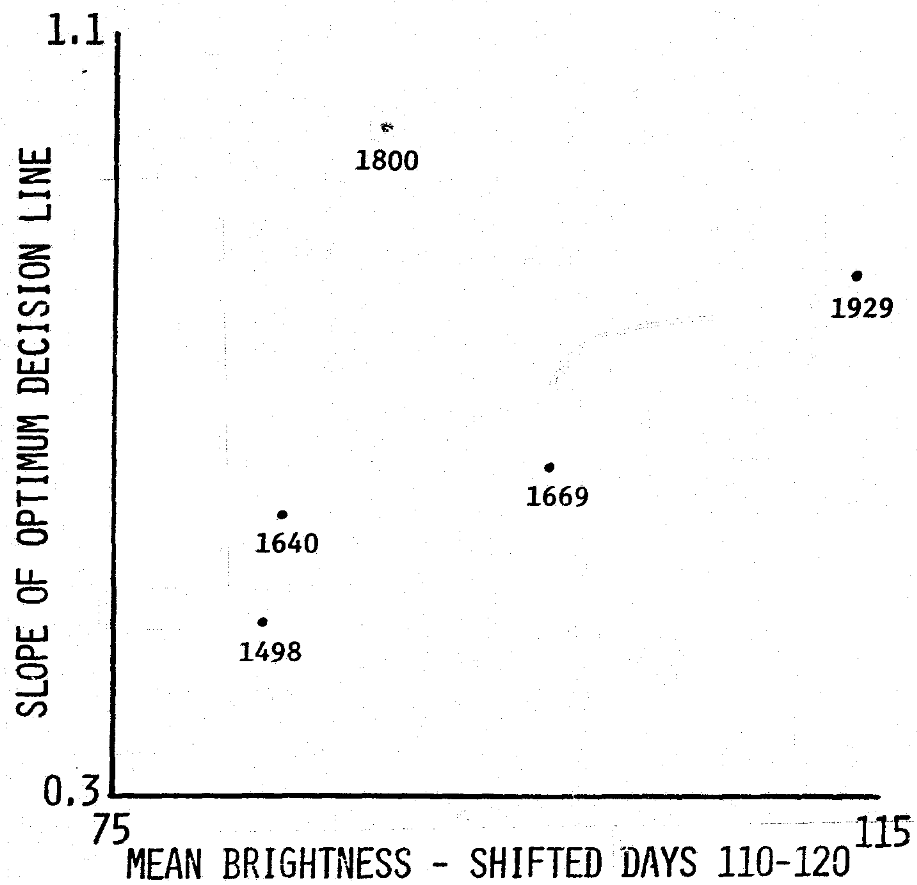
LANDSAT DATA ANALYSIS
(CONTINUED)

- MOST SEGMENTS SHOW EXPECTED SOIL BRIGHTNESS - SLOPE CORRELATION



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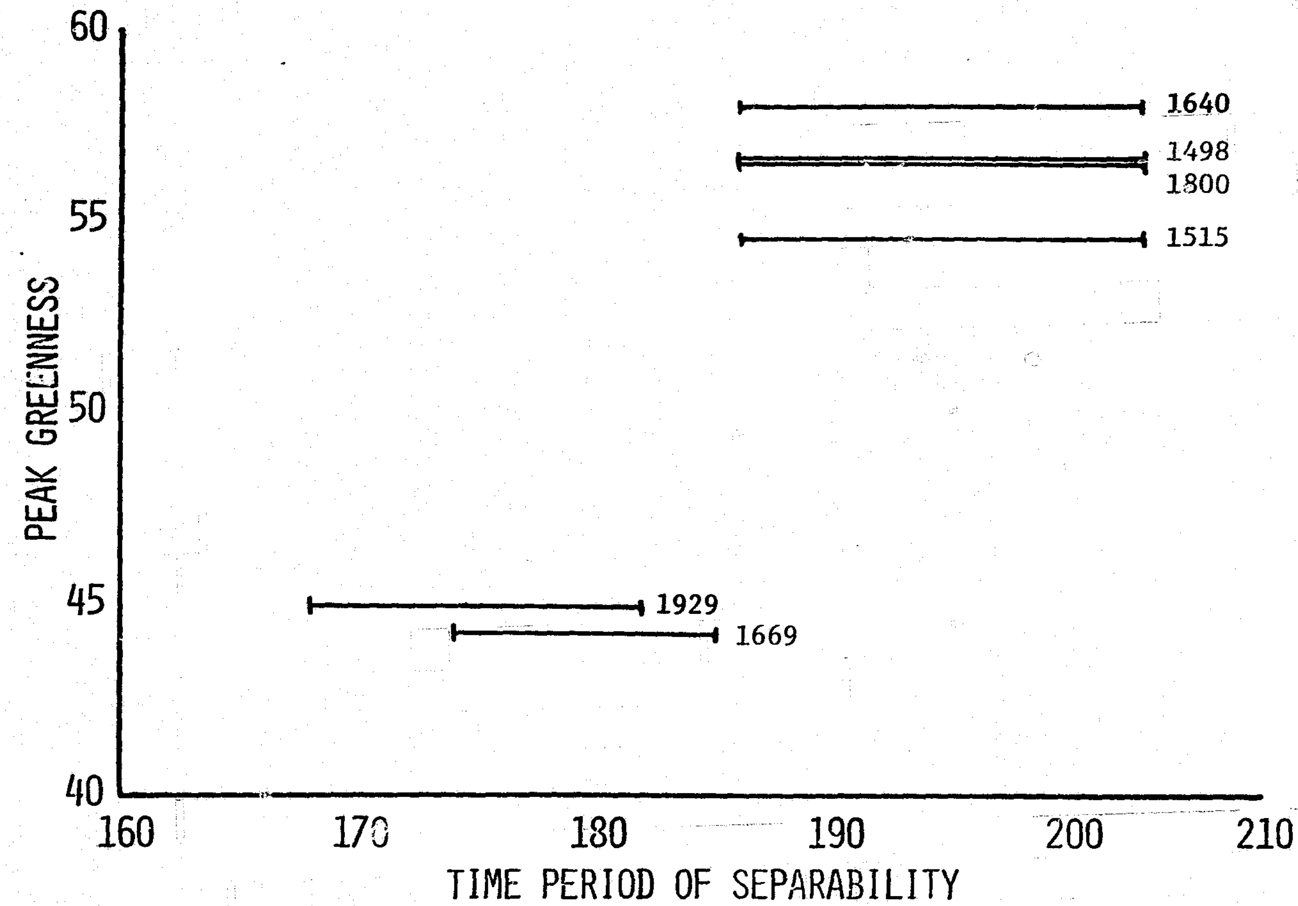
LANDSAT DATA ANALYSIS

(CONTINUED)

- CLEAR CORRELATION BETWEEN PEAK GREENNESS AND TIME PERIOD OF SEPARABILITY



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PROCEDURAL IMPLEMENTATION OF REFINED TECHNIQUE

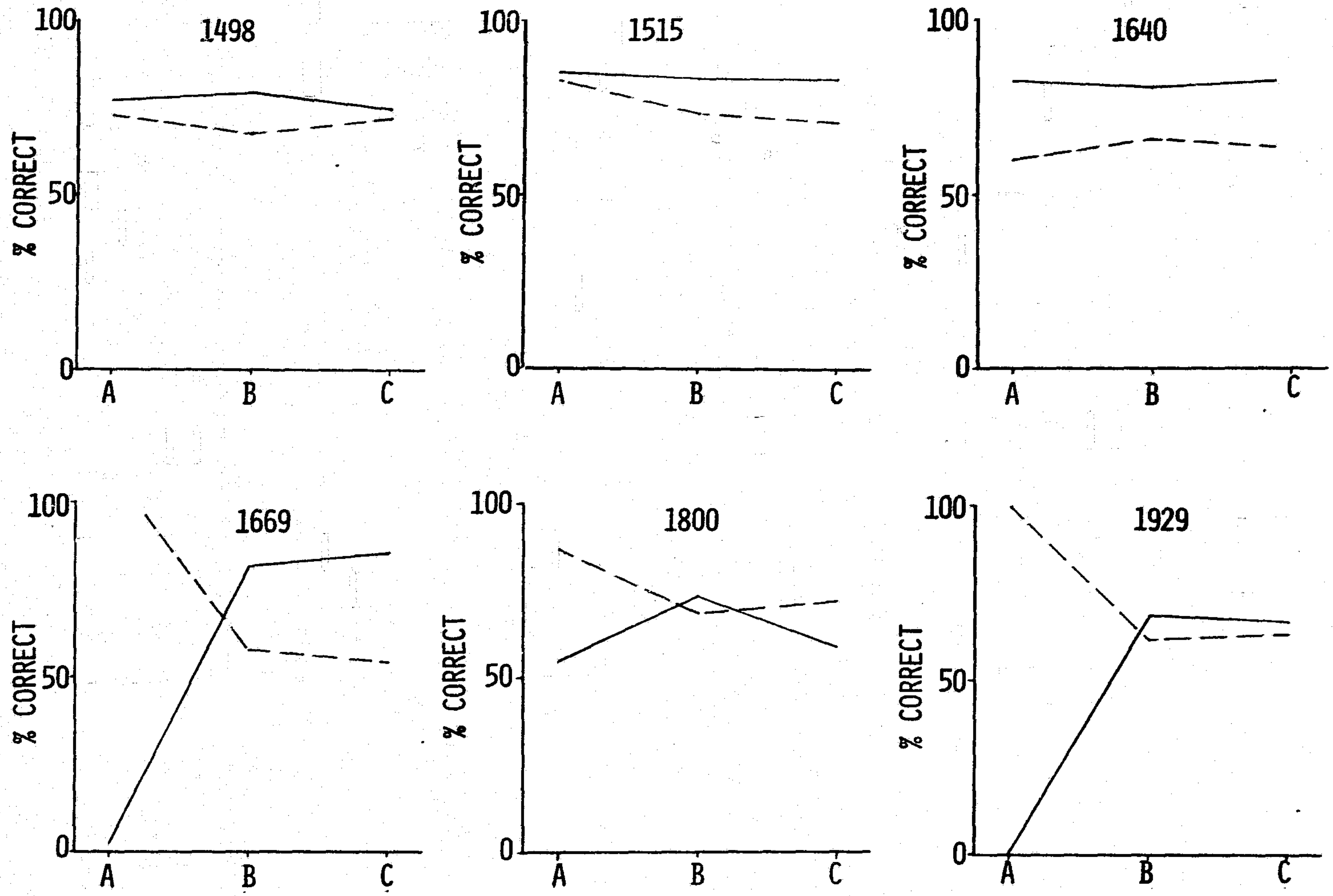
- Label Spring Small Grains
- Screen Segments
  - Adequate number and timing of acquisitions
  - Unusual behavior
- Estimate Crop Calendar Shift
  - Also provides segment specific greenness profile
- Flag Segments With Low Green Peak - Moisture Stressed
- Compute Mean Brightness for Small Grains
  - Shifted Days 110-120
- Modify Decision Line as Indicated by Green Peak and Early Brightness
- Assign labels

LANDSAT DATA ANALYSIS

LABELING RESULTS

A: ORIGINAL LABELING PROCEDURE
B: OPTIMUM LINEAR DISCRIMINANT
C: REVISED LABELING PROCEDURE (PRELIMINARY)

——— : SPRING WHEAT
– – – : BARLEY



LANDSAT DATA ANALYSIS

DETAILED LABELING RESULTS

	Ground Truth	Original Labeling Procedure		Optimum Linear Discriminant		Revised Labeling Procedure (Prelim.)	
		SPW/OSMG	% Correct	SPW/OSMG	% Correct	SPW/OSMG	% Correct
1498	Spring Wheat	806/239	77.1	846/220	79.4	802/264	75.2
	Barley	114/310	73.1	134/283	67.9	116/301	72.2
1515	Spring Wheat	2597/449	85.3	2805/551	83.6	2795/561	83.3
	Barley	421/2033	82.8	737/2022	73.3	801/1958	71.0
1640	Spring Wheat	4593/971	82.5	4493/1077	80.7	4601/969	82.6
	Barley	909/1363	60.0	770/1497	66.0	822/1445	63.7
1669	Spring Wheat	11/384	2.8	231/51	81.9	242/40	85.8
	Barley	10/261	96.3	75/102	57.6	81/96	54.2
1800	Spring Wheat	41/34	54.7	55/20	73.3	44/31	58.7
	Barley	133/871	86.8	315/679	68.3	278/716	72.0
1929	Spring Wheat	4/1346	0.3	678/312	68.5	662/328	66.9
	Barley	1/545	99.8	147/232	61.2	139/240	63.3

CONCLUSIONS

- IMPORTANT FACTORS INFLUENCING CROP SIGNATURES CAN BE DETECTED USING LANDSAT
- ADAPTATION OF THE SPRING WHEAT LABELING TECHNIQUE IN RESPONSE TO CHANGES IN THOSE FACTORS SUBSTANTIALLY IMPROVE LABELING ACCURACY
- CROP CALENDAR SHIFT ESTIMATION SIGNIFICANTLY ENHANCES PROSPECTS FOR UNDERSTANDING CROP SIGNATURES AND DEVELOPING VIABLE LABELING PROCEDURES

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PLANS

- DEFINE RELATIONSHIPS BETWEEN SOIL BRIGHTNESS AND DECISION LINE SLOPE AND PEAK GREENNESS AND TIME PERIOD FOR LABELING UTILIZING A MORE EXTENSIVE DATA BASE
- INSTALL REFINED LABELER IN PROCEDURE M
- TEST AND EVALUATE REFINED LABELER

MACHINE PROCESSING TASK

- MAJOR ELEMENTS
  - DATA NORMALIZATION STUDIES
  - STRATIFICATION, SAMPLING AND ESTIMATION
  - TEST AND EVALUATION
  - SYSTEM ERROR MODEL DEVELOPMENT
  - ADVANCED TECHNOLOGY STUDIES
- FOCAL POINTS:
  - LANDSAT III
  - PROCEDURE M
  - WHEAT

ELEMENTS OF MACHINE PROCESSING

- DATA NORMALIZATION STUDIES
  - ANALYZE LANDSAT 3 SPECTRAL DATA STRUCTURE
  - EXAMINE LANDSAT 2 CALIBRATION DRIFT
- STRATIFICATION, SAMPLING AND ESTIMATION
  - EVALUATE ALTERNATIVE SPECTRAL STRATIFICATION TECHNIQUES
  - REDUCE BIAS DUE TO CURRENT PROCEDURE M SAMPLING STRATEGY
  - EXAMINE ALTERNATIVE ESTIMATION STRATEGIES
- TEST AND EVALUATION
  - EXAMINE ANALYST LABELING IN A FIELD-TARGET ENVIRONMENT
  - EVALUATE SPRING WHEAT CONFIGURATION OF PROCEDURE M
  - EXPLORE MULTICROP APPLICATION OF PROCEDURE M
  - TRANSFER PROCEDURE M TECHNOLOGY TO JSC
- SYSTEM ERROR MODEL DEVELOPMENT
  - REPRESENT ERROR SOURCES IN PROCEDURE M ANALYTICALLY
  - DETERMINE PERFORMANCE MEASURES
- ADVANCED TECHNOLOGY (CANDIDATE TOPICS)
  - REGISTRATION OF MULTI-TEMPORAL DATA
  - FULL-FRAME SAMPLING ENVIRONMENT
  - CROP INVENTORY IN PROBLEM AREAS (SMALL FIELDS, CLOUD COVER)
  - CONCEPTUALIZATION OF EARLY WARNING

LANDSAT-3 TO LANDSAT-2 CALIBRATION TRANSFORMATION

PETER F. LAMBECK

LANDSAT-3 TO LANDSAT-2 CALIBRATION TRANSFORMATION

OBJECTIVE

- DETERMINE A MULTIPLICATIVE AND ADDITIVE TRANSFORMATION WHICH ALTERS LANDSAT-3 DATA TO SIMULATE LANDSAT-2 DATA

- OBTAIN SUFFICIENT ACCURACY FOR THE TRANSFORMATION SO THAT SCREEN AND XSTAR WILL APPLY TO LANDSAT-3 DATA IN A MANNER WHICH IS EQUIVALENT TO THEIR LANDSAT-2 PERFORMANCE

STEPS IN THE DEVELOPMENT OF A LANDSAT 3-2 CALIBRATION TRANSFORMATION

- OBTAINED DATA FOR 31 9-DAY LANDSAT 3-2 ACQUISITION PAIRS
- CALCULATED SCENE DIAGNOSTIC VALUES FOR EACH ACQUISITION
  - (GREEN ARM MEAN + SOIL MEAN)/2
  - SCENE MEAN "YELLOW" VALUE
- CALCULATED INITIAL LEAST SQUARES ESTIMATE OF TRANSFORMATION
- ELIMINATED 10 PAIRS WITH EXCESSIVE RESIDUAL ERRORS, PRESUMABLY CAUSED BY SCENE EFFECTS:
  - DISSIMILAR HAZE CONDITIONS ("YELLOW" VALUES)
  - DISSIMILAR SCENE DEVELOPMENT
  - OTHER CAUSES?
- RECALCULATED ESTIMATE OF TRANSFORMATION USING 21 REMAINING PAIRS
- PRODUCED FINAL ESTIMATE OF TRANSFORMATION USING MERGED 9-DAY PAIR CLUSTER MEANS (TO REPRESENT A WIDER SIGNAL RANGE)
  - MISREGISTERED CLUSTERS WERE MOSTLY AVOIDED IN THE ESTIMATION PROCEDURE

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RESULTS AND EVALUATION OF THE LANDSAT 3-2 CALIBRATION TRANSFORMATION

- THE FOLLOWING PURELY MULTIPLICATIVE TRANSFORMATION APPEARS TO BE ADEQUATE AND IS RECOMMENDED:

$$L2_I = A_I L3_I \qquad A = \begin{pmatrix} 1.1371 \\ 1.1725 \\ 1.2470 \\ 1.1260 \end{pmatrix}$$

  - COEFFICIENTS DIFFER BY 2 TO 6% FROM GODDARD PRELAUNCH ESTIMATE EXCEPT FOR BAND 6 (DIFFERS BY ~18%)
  - TRANSFORMATION IS ROUGHLY SIMILAR TO LEC TRANSFORMATION (DIFFERS BY 2 TO 6%)
- CORRECTED LANDSAT-3 DATA HAS TASSELED CAP COMPONENTS WHICH ARE SIMILAR TO LANDSAT-2 COMPONENTS
- SCREEN AND XSTAR PERFORM REASONABLY ON THE CORRECTED LANDSAT-3 DATA

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STRATIFICATION, SAMPLING AND ESTIMATION

OBJECTIVE

DEVELOP A STRATIFICATION, SAMPLING AND ESTIMATION FRAMEWORK IN WHICH TO EVALUATE PROBLEMS ASSOICATED WITH MULTICROP INVENTORY

STRATIFICATION, SAMPLING, ESTIMATION

APPROACH

- UTILIZE PROCEDURE M AS A TEST-BED
- REDUCE BIAS CAUSED BY SPATIAL SAMPLING
  - EVALUATE ALTERNATIVE FEATURE EXTRACTION ALGORITHMS
  - EXAMINE TECHNIQUES TO SAMPLE LITTLE BLOBS
- EXAMINE ALTERNATIVE SPECTRAL STRATIFICATION STRATEGIES
  - EVALUATE DYNAMIC APPROACHES
    - .. UNSUPERVISED APPROACHES
    - .. TOLERANCE BLOCK APPROACHES
    - .. CLASSY
  - CONSIDER STATIC APPROACHES
    - .. DESIGNATED OTHER
    - .. STATIC SPECTRAL STRATIFICATION
- EVALUATE ALTERNATIVE ESTIMATION STRATEGIES
  - EVALUATE POTENTIAL OF CLASSIFIERS BASED ON LINEAR RULE

STRATIFICATION, SAMPLING, ESTIMATION

PROGRESS

- STUDY OF TOLERANCE BLOCK APPROACH TO SPECTRAL STRATIFICATION CONDUCTED
- ALTERNATIVE ALGORITHM TO BLOB DEVELOPED
- PROCEDURE M CONFIGURATION UTILIZING SMALL FIELDS DESIGNED
- ESTIMATION CONFIGURATION USING ERIM OPTIMUM LINEAR DECISION RULE DEFINED

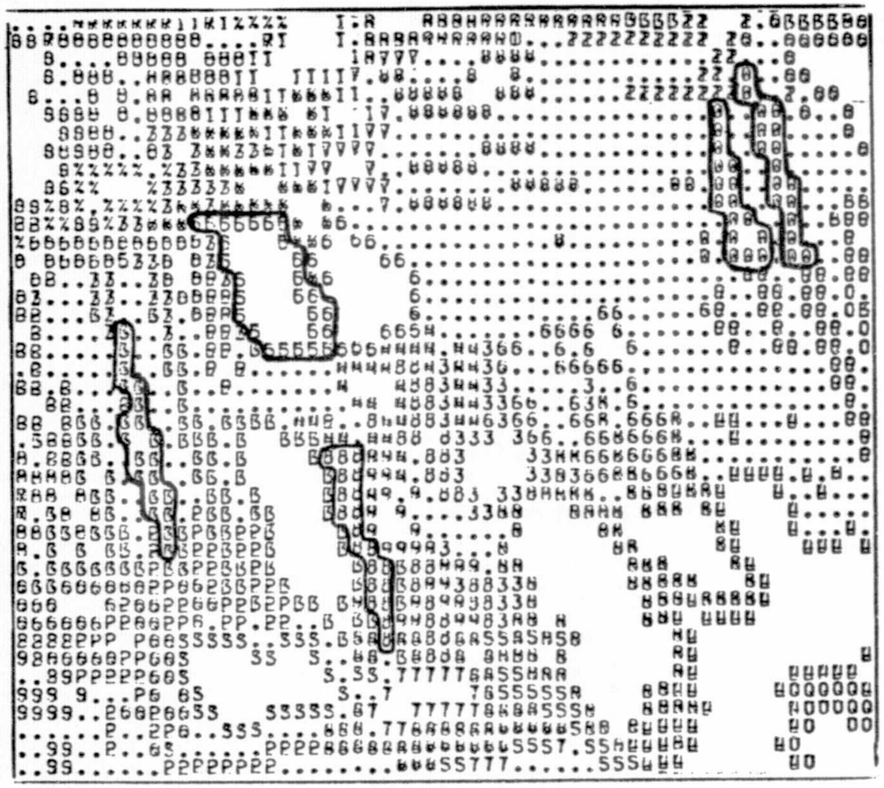
DEVELOPMENT OF ENHANCED BLOB ALGORITHM (SUPERB)

- SUCCESSOR OF BLOB
- ATTRIBUTES
  - QUASI-FIELDS ARE CONTIGUOUS
  - LARGER FIELDS ARE NOT DISCONNECTED
  - MORE EFFICIENT ALGORITHM
- DISTANCE MEASURE REPLACED BY CONTIGUITY CRITERION

FEASIBILITY OF SAMPLING SMALL FIELDS

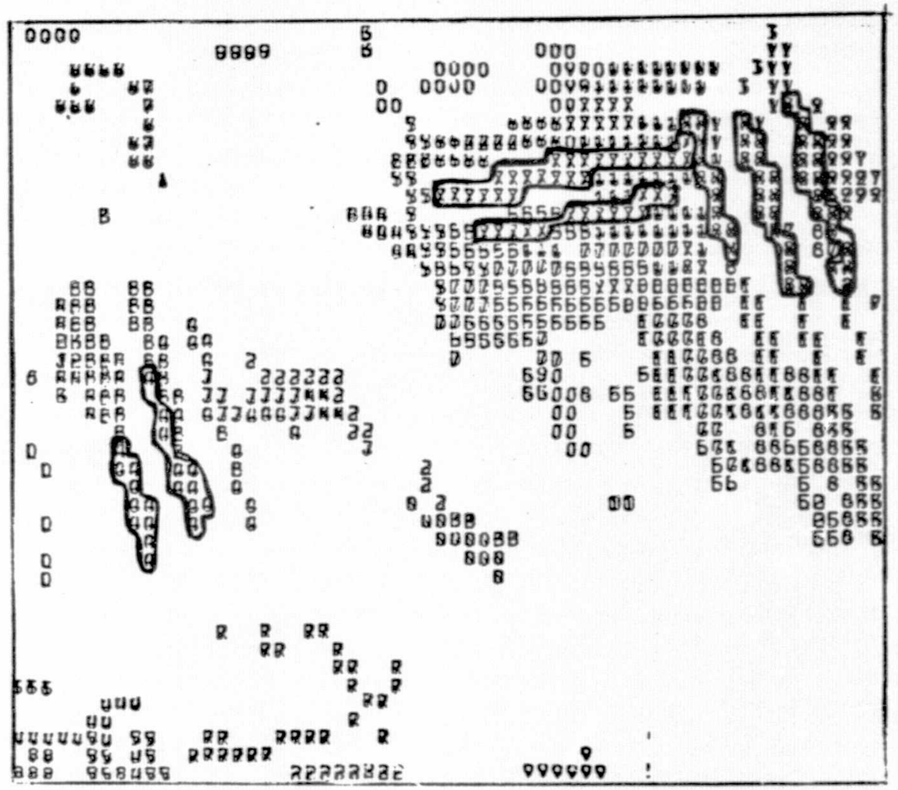
SEGMENT 1650

BIG BLOBS



(LITTLE BLOBS MASKED AS PERIODS)

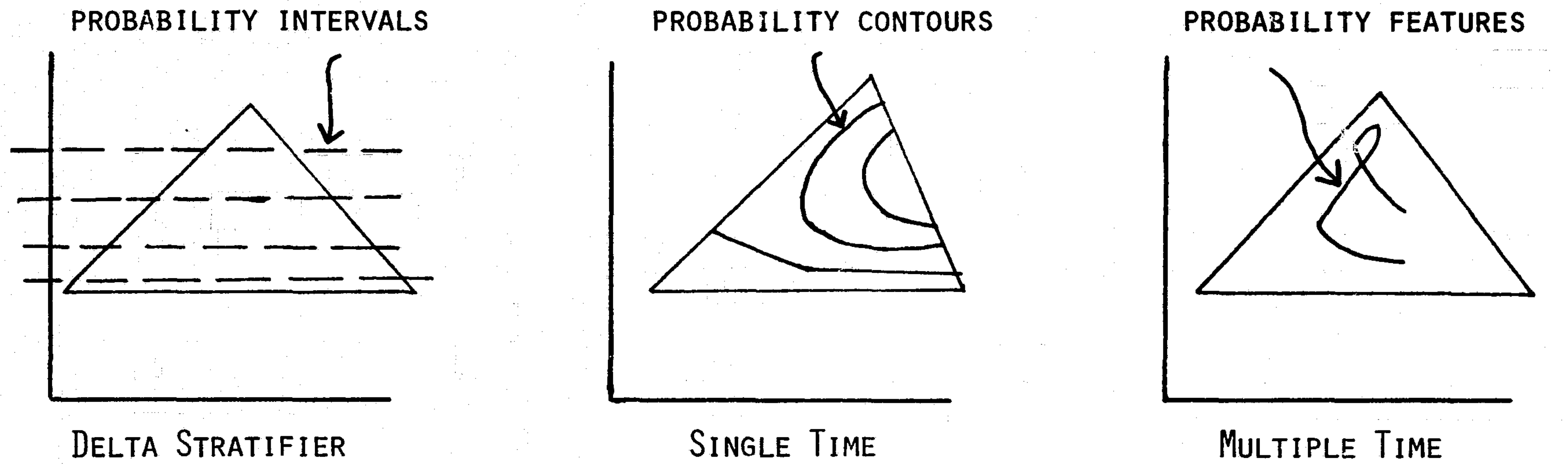
LITTLE BLOBS



(BIG BLOBS MASKED AS BLANKS)

CONCEPT OF STATIC STRATIFICATION

SAMPLE $N \propto P(1-P)A$



USING BLIND SITE DATA PARTITIONED QUALITATIVELY BY CROP STRESS CONDITIONS ETC. DETERMINE PRIOR PROBABILITY THAT 'WHEAT' APPEARS IN EACH STRATA

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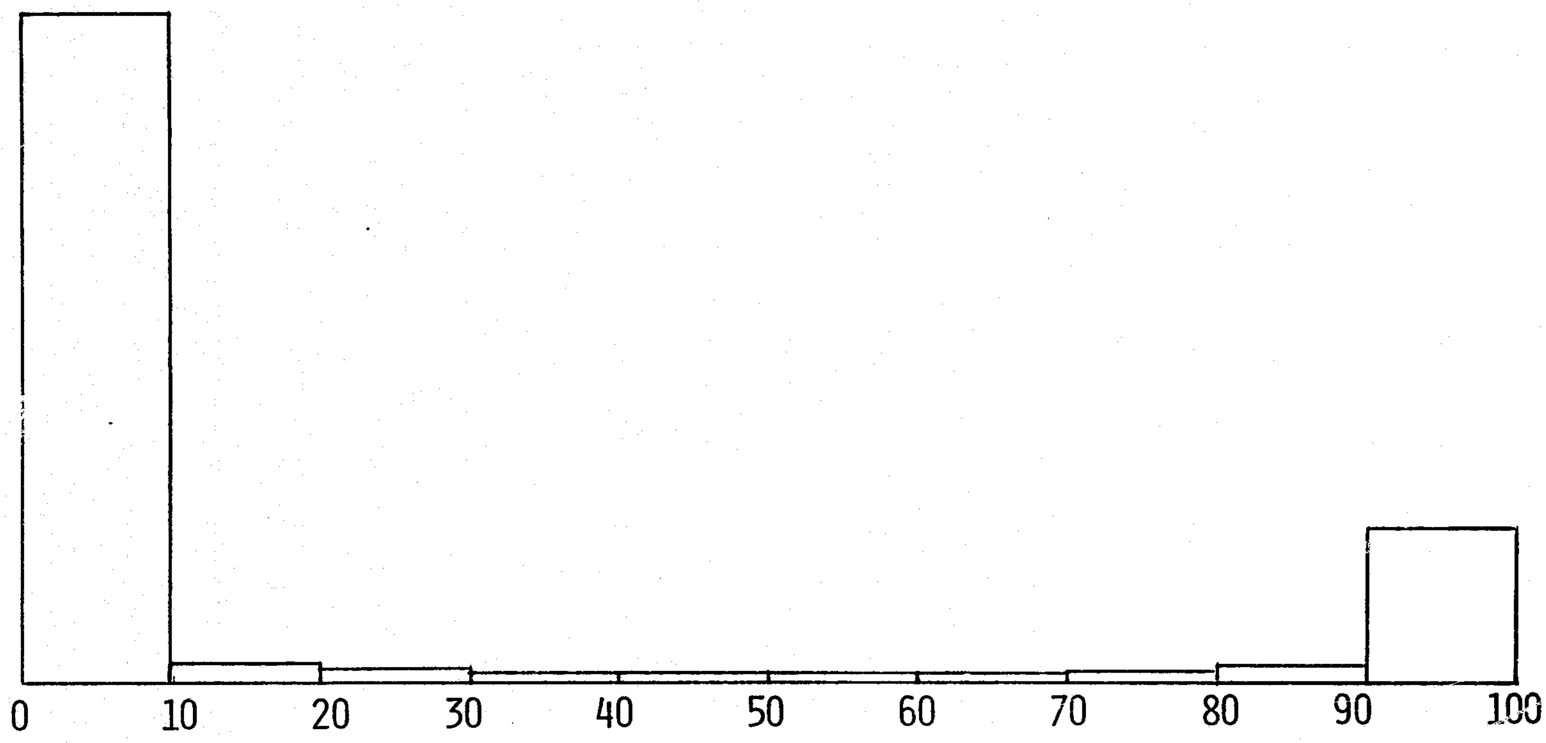
STUDIES IN STRATIFICATION TO REDUCE SAMPLING VARIANCE

WYMAN RICHARDSON

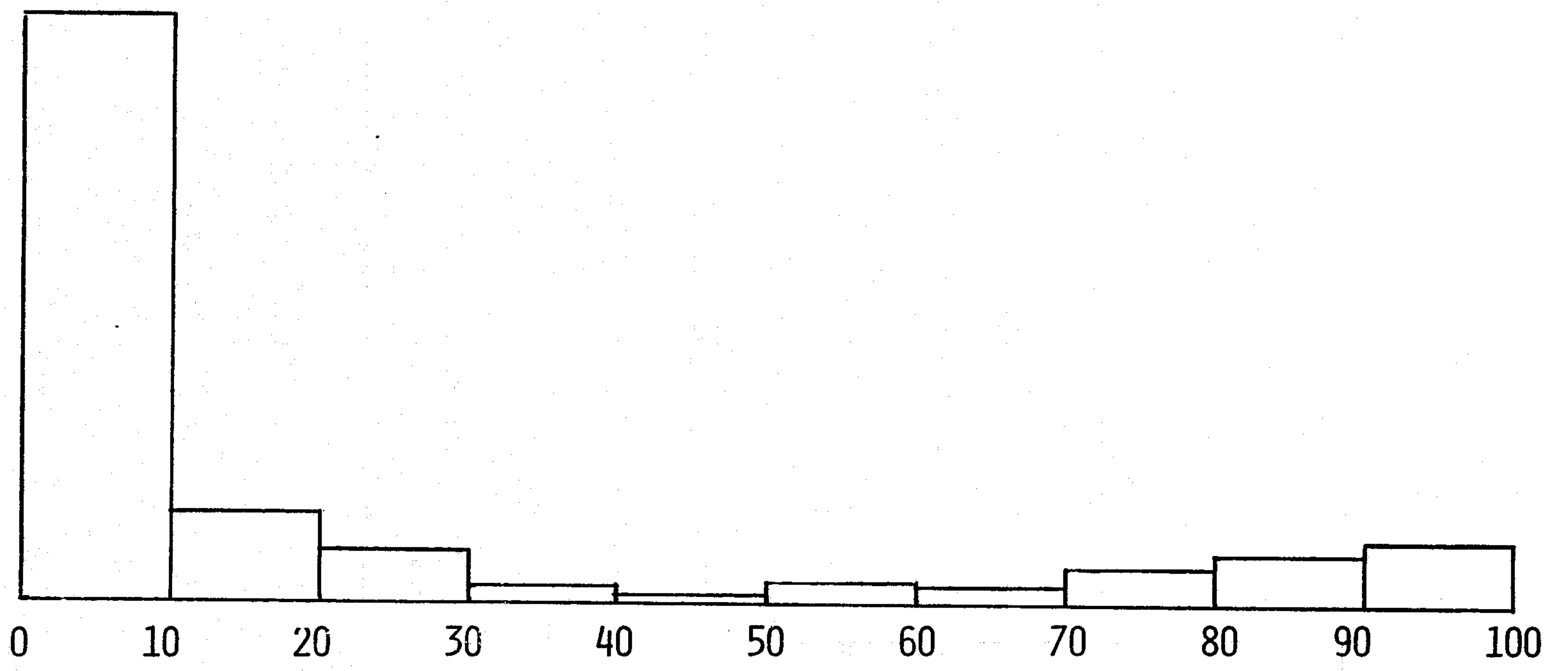
ERIM

PROCEDURE M -

- CLUSTERS PIXELS SPECTRALLY AND SPATIALLY INTO FIELD-LIKE GROUPS CALLED "BLOBS"
- CLUSTERS BLOBS INTO SPECTRAL STRATA



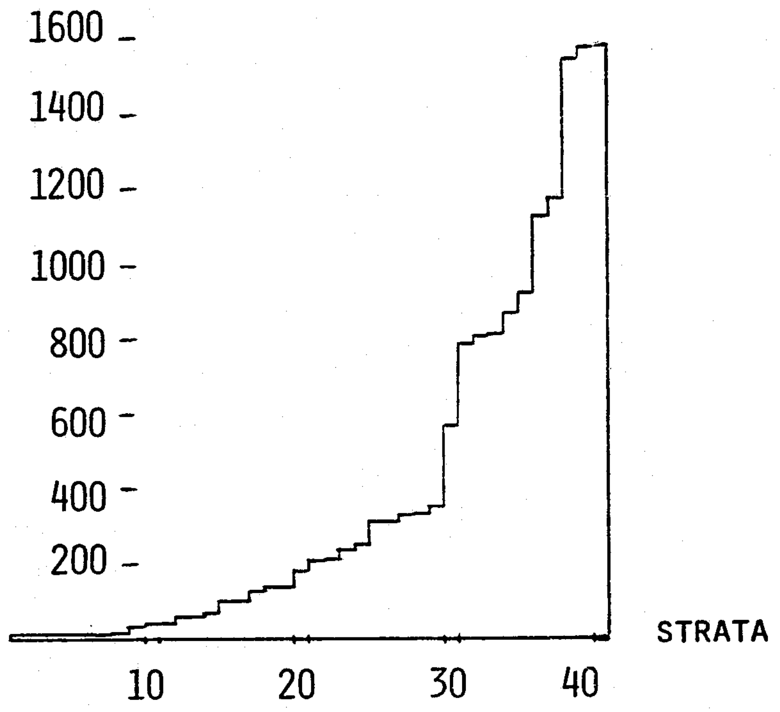
HISTOGRAM OF PERCENT WHEAT IN BLOB INTERIORS
FOR 12 KANSAS SEGMENTS



HISTOGRAM OF PERCENT WHEAT IN SPECTRAL STRATA
FOR 12 KANSAS SEGMENTS

OBJECTIVE:

IMPROVE SPECTRAL STRATIFICATION



PIXEL DISTRIBUTION FOR BCLUST STRATA

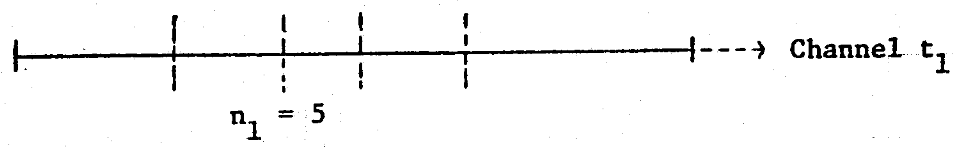
SEGMENT 1165

OBJECTIVE:

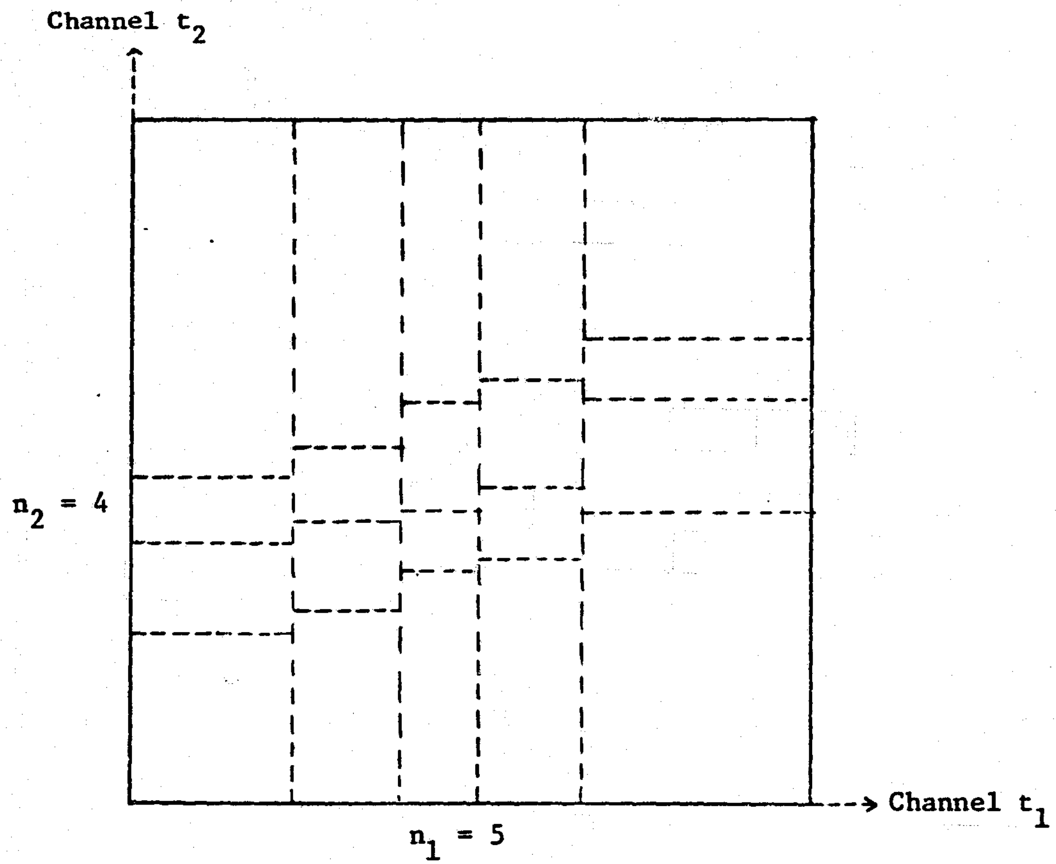
IMPROVE SPECTRAL STRATIFICATION

APPROACH:

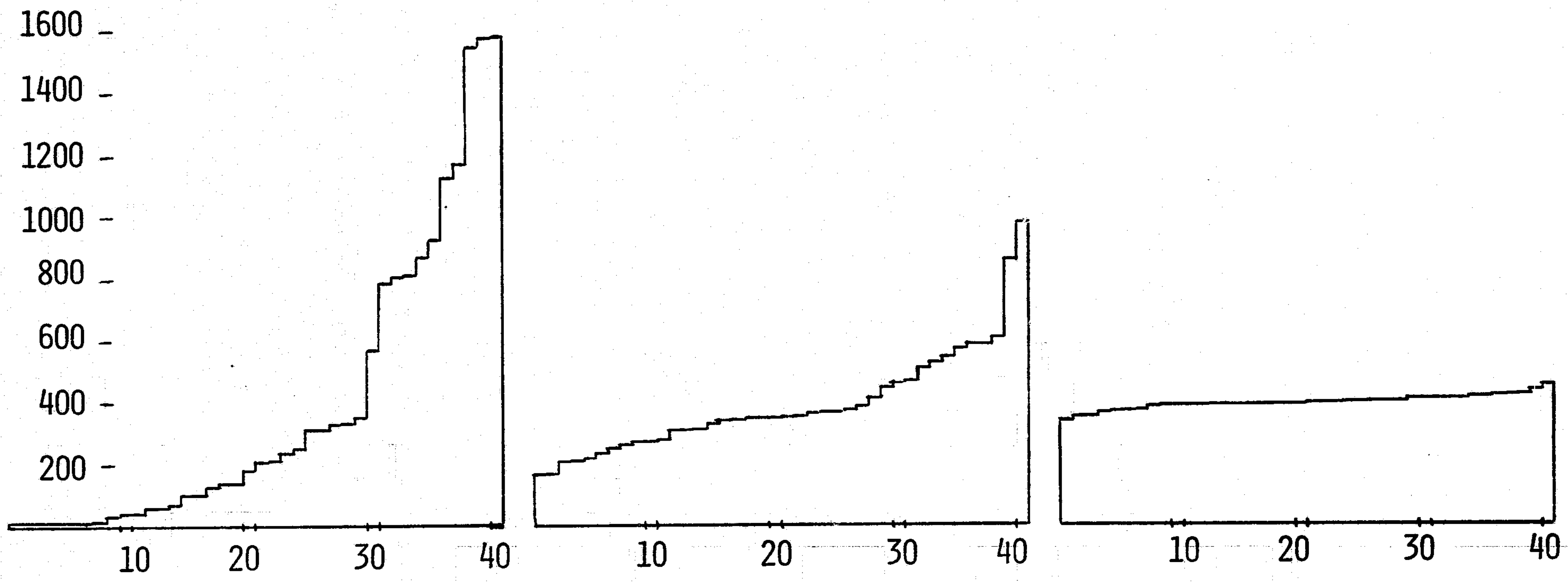
TOLERANCE BLOCK CLUSTERING ALGORITHM



FIRST CUT TO CREATE TOLERANCE BLOCKS



FIRST AND SECOND CUTS TO CREATE TOLERANCE BLOCKS



BLCUST

BLOCK-SEEDED CLUSTERS

BLOCKS AS CLUSTERS

PIXEL DISTRIBUTIONS FOR 3 CLUSTERING ALGORITHMS

SEGMENT 1165

$$R.V. = \frac{\sum N_I P_I (1-P_I)}{NP(1-P)}$$

N_I = NUMBER OF PIXELS IN STRATUM I

N = NUMBER OF PIXELS IN THE SEGMENT

P_I = PROPORTION OF WHEAT IN STRATUM I

P = PROPORTION OF WHEAT IN THE SEGMENT

R.V. WITH INTEGER ALLOCATIONS

$$\frac{\sum \left(\frac{N_I}{N}\right)^2 \frac{P_I(1-P_I)}{A_I}}{\frac{P(1-P)}{A}}$$

$\left.\begin{array}{l} N_I \\ N \end{array}\right\}$ NUMBER OF PIXELS IN STRATUM I OR SEGMENT

$\left.\begin{array}{l} P_I \\ P \end{array}\right\}$ PROPORTION OF WHEAT IN STRATUM I OR SEGMENT

$\left.\begin{array}{l} A_I \\ A \end{array}\right\}$ NUMBER OF SAMPLE BLOBS IN STRATUM I OR SEGMENT

PERFORMANCE MEASURE:

THE FIXED-SAMPLE R.V.

$$\frac{\sum \left(\frac{N_I}{N}\right)^2 \frac{P_I(1-P_I)}{A_I}\left(\frac{B_I-A_I}{B_I-1}\right)}{\frac{P(1-P)}{A}\left(\frac{B-A}{B-1}\right)}$$

N_I = NUMBER OF PIXELS IN STRATUM I

P_I = PROPORTION OF WHEAT IN STRATUM I

A_I = NUMBER OF SAMPLE BLOBS IN STRATUM I

B_I = NUMBER OF BLOBS IN STRATUM I

$$\left.\begin{array}{l} N \\ P \\ A \\ B \end{array}\right\} \text{SAME FOR THE SEGMENT}$$

EXPERIMENT

- 3 Clustering Algorithms
  - BCLUST
  - Tolerance Blocks
  - Clusters Seeded By Block Means
- 12 Kansas Blind Sites
- Winter Wheat Estimation
- 3 Biowindows
- Brightness And Greenness From Each Biowindow
- Sample Of Size 100 Blobs Assumed

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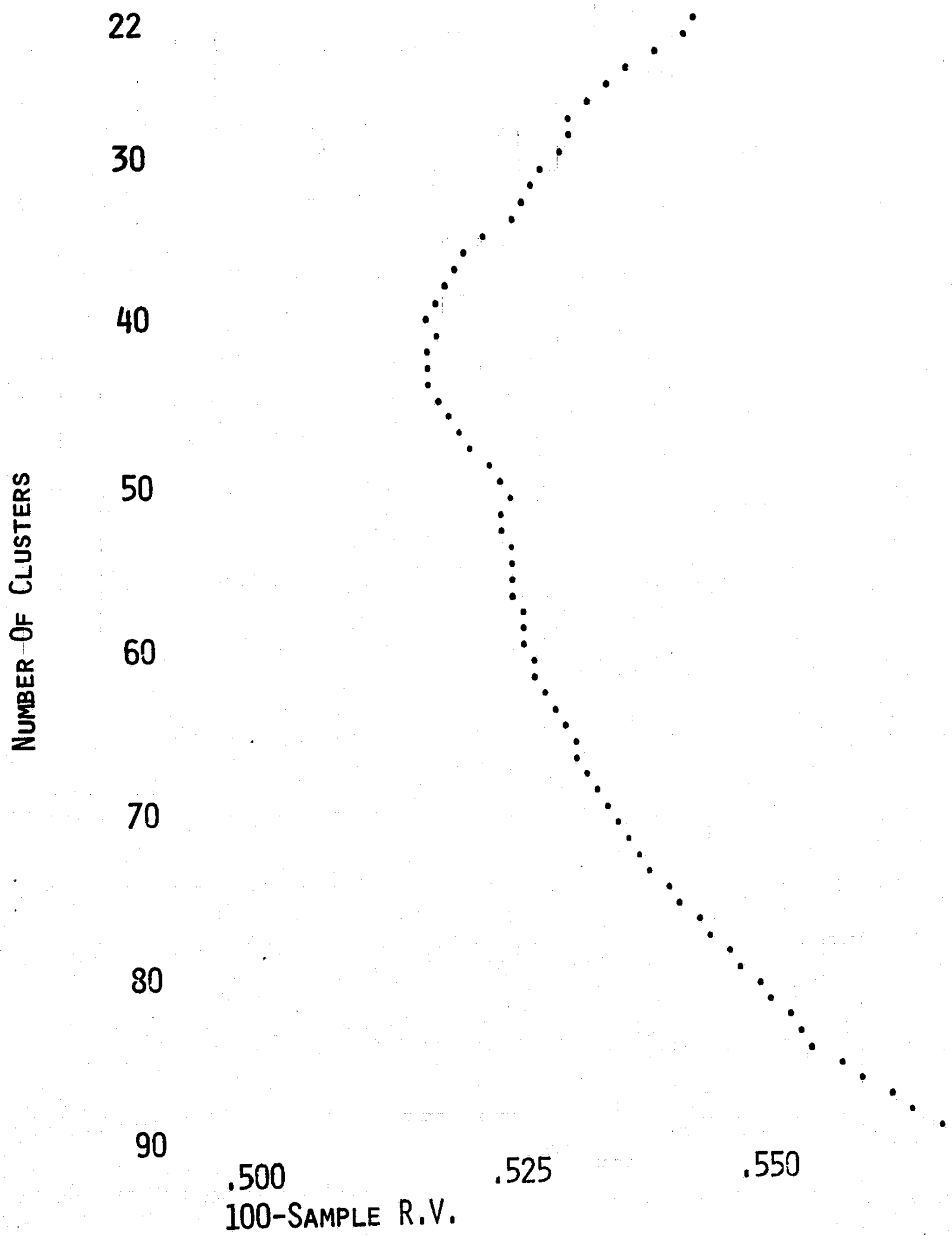

BCLUST PERFORMANCE AS A FUNCTION
OF THE NUMBER OF CLUSTERS

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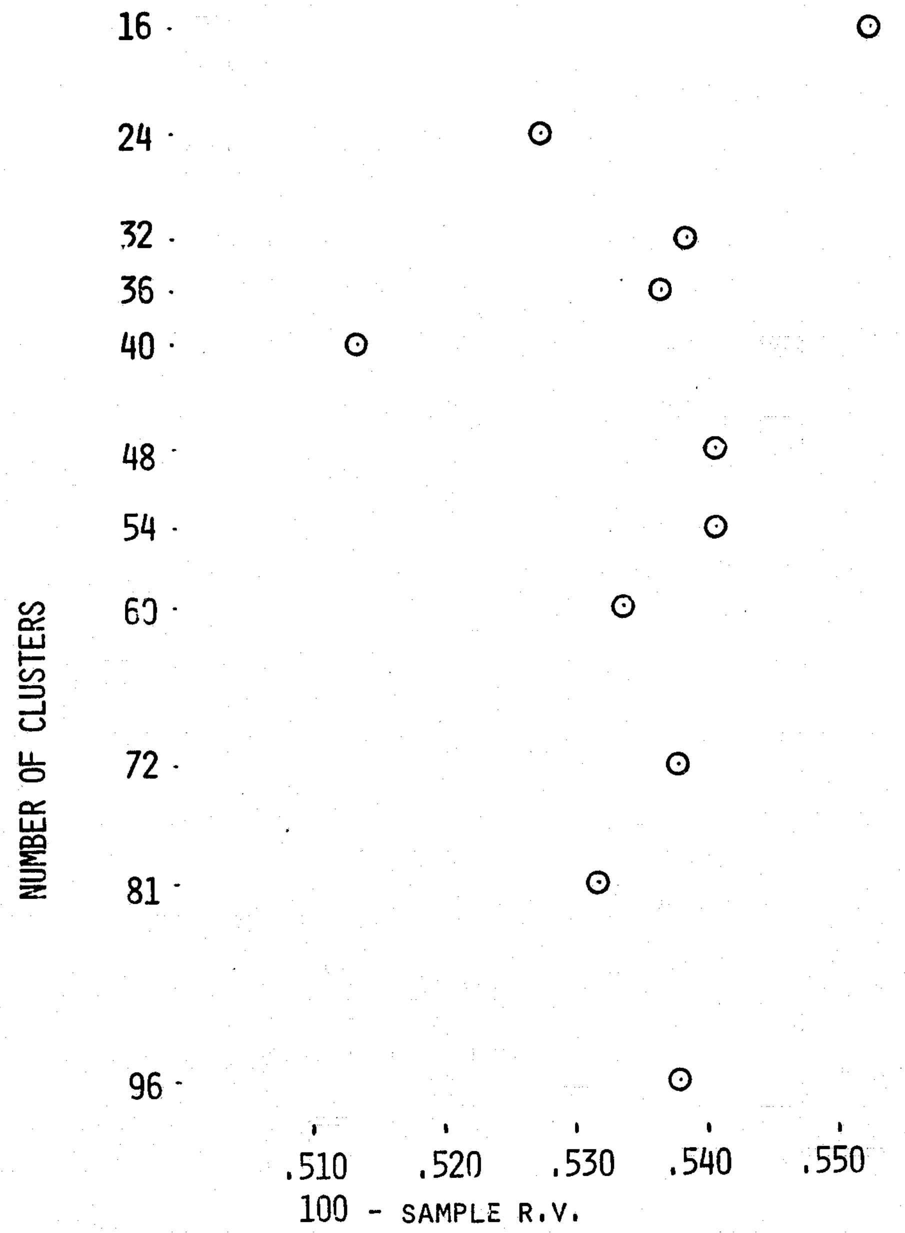
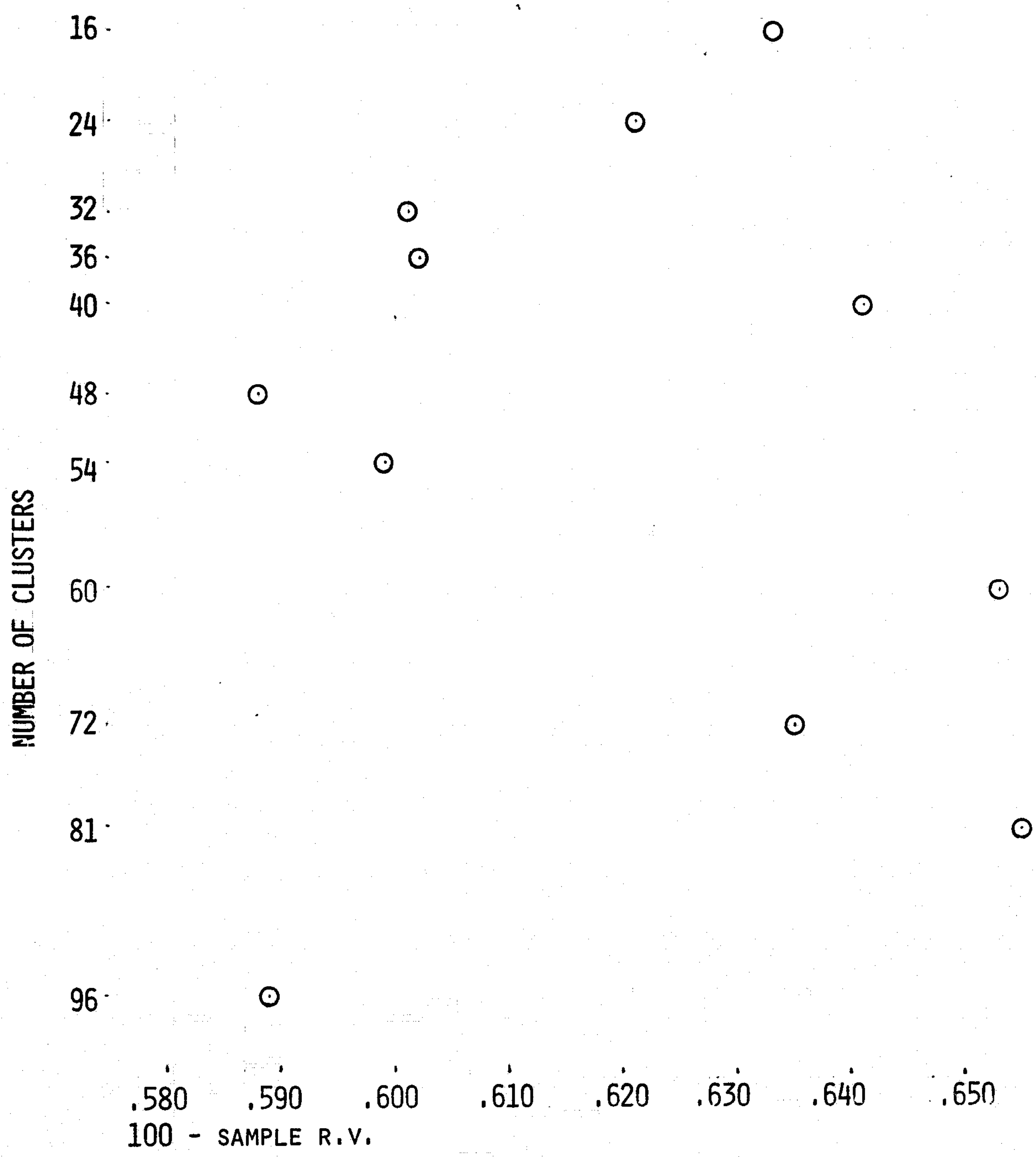


PERFORMANCE OF BLOCK SEEDS AS A FUNCTION OF THE NUMBER OF CLUSTERS



PERFORMANCE OF BLOCKS AS CLUSTERS AS A FUNCTION OF THE NUMBER OF CLUSTERS

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COMPARISON OF 3 CLUSTERING ALGORITHMS
AT THEIR OPTIMAL NUMBER OF CLUSTERS
PERFORMANCE MEASURE IS 100-SAMPLE R.V.

SEGMENT	BLOB INTERIOR R.V.	BCLUST 40 CLUSTERS	BLOCK SEEDS 40 CLUSTERS	BLOCKS 48 CLUSTERS
1020	.039	.181	.217	.239
1035	.187	.624	.560	.578
1165	.204	.832	.922	.872
1851	.155	.383	.404	.495
1852	.136	.423	.454	.614
1861	.090	.355	.389	.396
1865	.086	.610	.580	.615
1886	.168	.502	.452	.532
1163	.283	.622	.621	.725
1167	.178	.652	.614	.813
1860	.145	.385	.361	.420
1887	.168	.643	.588	.758
AVERAGE	.153	.518	.514	.588
AVERAGE DIFFERENCE			.004	-.074
T			.31	-3.47
SIGNIFICANCE			NOT SIGNIFICANT	SIGNIFICANT AT .005

INFORMATION THEORETIC PERFORMANCE MEASURES

(W. A. MALILA)

- CONJECTURE: THE WELL-DEVELOPED PRINCIPLES OF INFORMATION THEORY SHOULD BE APPLICABLE TO EVALUATION AND DESIGN ASPECTS OF INFORMATION EXTRACTION AND AREA ESTIMATION SYSTEMS THAT USE REMOTELY SENSED DATA.

- OBJECTIVES: DETERMINE THE VALIDITY OF THE CONJECTURE AND, IF VALID:
  - DEVELOP PERFORMANCE MEASURES THAT SUPPLEMENT OR PARALLEL CURRENT MEASURES
  - CONSIDER SYSTEM DESIGN IMPLICATIONS

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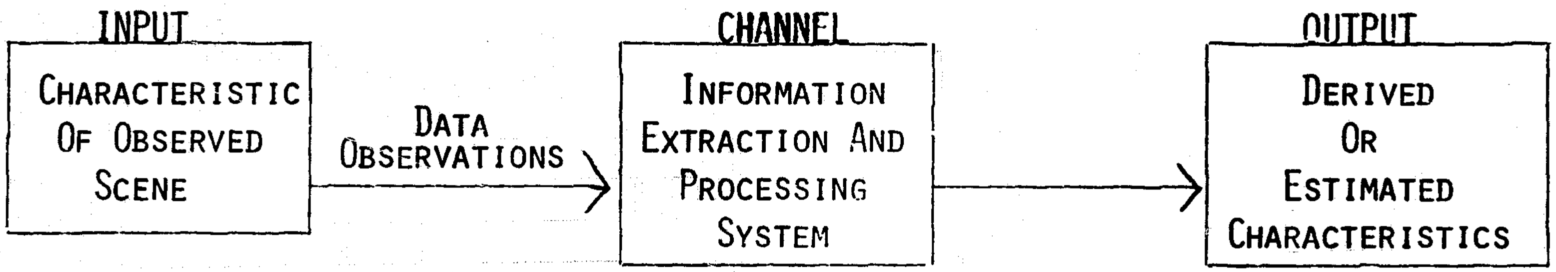
INFORMATION THEORETIC PERFORMANCE MEASURES (CONTINUED)

APPROACH

- VIEW INFORMATION EXTRACTION SYSTEMS AS COMMUNICATION CHANNELS WITH:
  - SCENE-DEPENDENT INPUT INFORMATION
  - "NOISY" PROCESSING SYSTEMS THAT LOSE INFORMATION AND/OR INTRODUCE ERRORS
  - OUTPUT INFORMATION THAT IDEALLY WOULD MATCH THAT OF THE INPUT



PROGRESS

- ESTABLISHED THE APPROACH AND VIEWPOINT
- DEVELOPED A CANDIDATE MEASURE OF STRATIFICATION PERFORMANCE AND PERFORMED LIMITED TESTING IN PROCEDURE M TESTS
- DEVELOPED ADDITIONAL CANDIDATE MEASURES
- BEGAN CONSIDERATION OF OTHER ASPECTS

BASIC CONCEPTS

- THE SELF INFORMATION ASSOCIATED WITH THE OCCURRENCE OF STATE x_I WHICH OCCURS WITH PROBABILITY $P(x_I)$ IS DEFINED TO BE:

$$I(x_I) = \text{LOG } \frac{1}{P(x_I)} = -\text{ LOG } P(x_I)$$

(THE MORE RARE THE EVENT, THE GREATER IS THE AMOUNT OF INFORMATION ASSOCIATED WITH ITS OCCURRENCE)

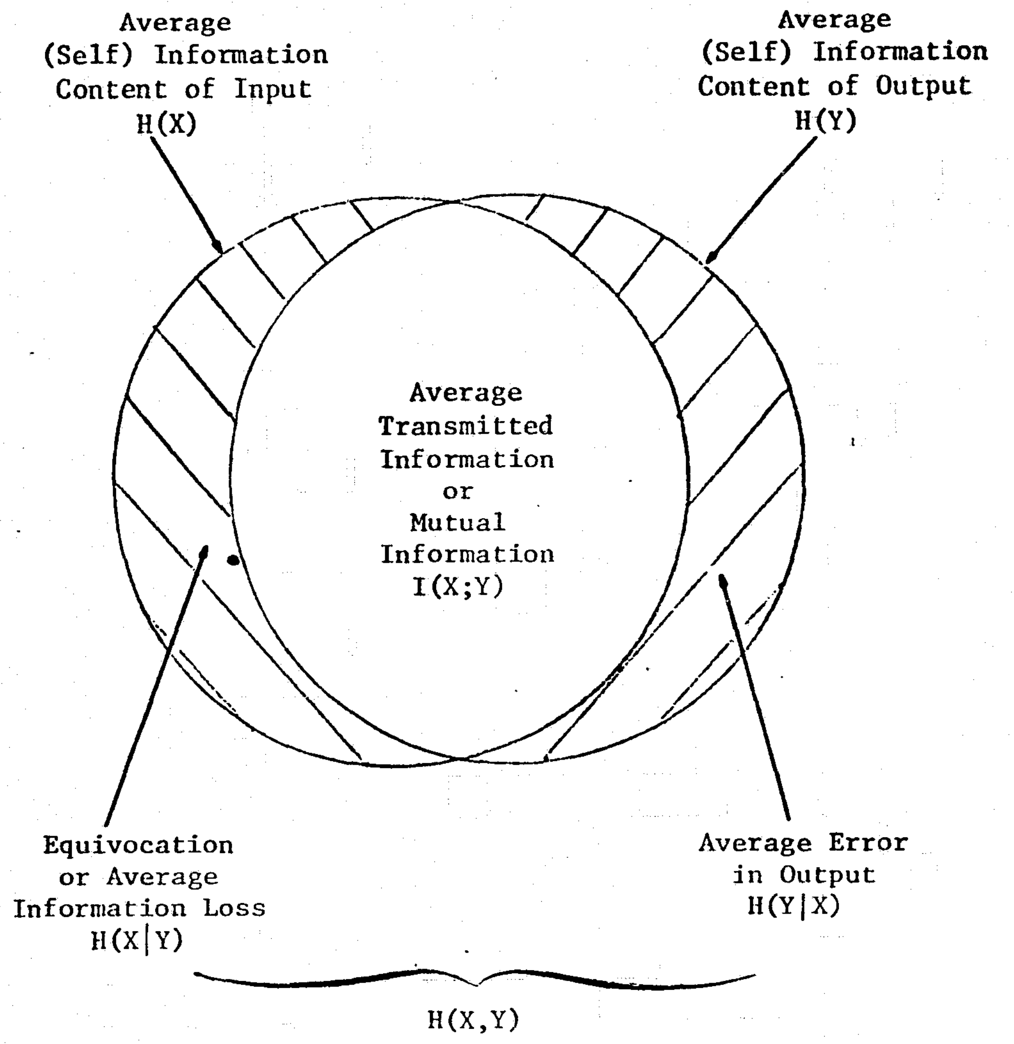
- ENTROPY IS THE AVERAGE AMOUNT OF INFORMATION ASSOCIATED WITH REPEATED OBSERVATIONS OF A STATE VARIABLE:

$$H(X) = -\sum_{I=1}^{M} P(x_I) \text{ LOG } P(x_I)$$

$\left(H_{MAX} = \text{LOG } M \text{ AND OCCURS WHEN } P(x_I) = \frac{1}{M}\right)$

- MUTUAL INFORMATION IS THE EXPECTED AVERAGE INFORMATION EXCHANGED FROM INPUT X TO OUTPUT Y

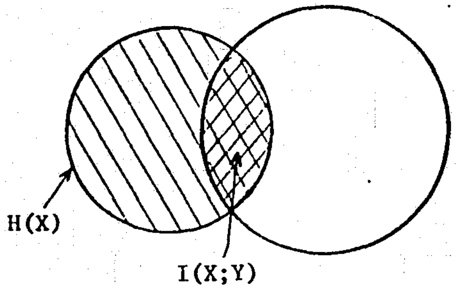
$$I(X;Y) = \sum_{I=1}^{M} \sum_{J=1}^{N} P(x_I, y_J) \text{ LOG } \left(\frac{P(x_I | y_J)}{P(x_I)}\right)$$



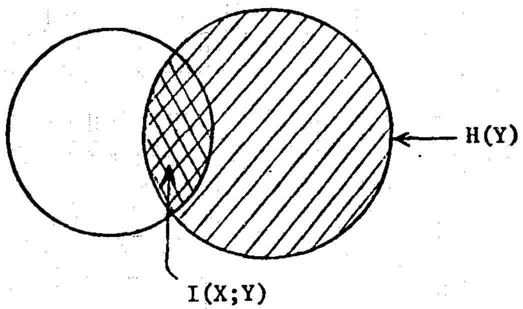
DIAGRAMMATIC REPRESENTATION OF AVERAGE INFORMATION RELATIONSHIPS FOR TWO VARIABLES

CANDIDATE PERFORMANCE MEASURES
(NORMALIZED MUTUAL INFORMATION)

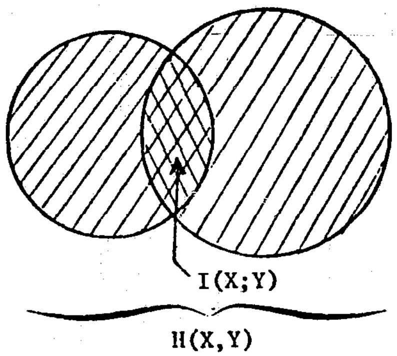
- COMMON CHARACTERISTICS
  - STRATUM PROPORTIONS SUBSTITUTED FOR STATE PROBABILITIES IN CALCULATIONS
  - MAXIMUM VALUE = 1 INDICATES NO INFORMATION LOSS AND/OR NO ERROR
  - MINIMUM VALUE = 0 INDICATES NO INFORMATION TRANSFER
  - DIRECT APPLICATION TO MORE THAN TWO CLASSES
- CANDIDATE NORMALIZATION TERMS (AND MEASURES):



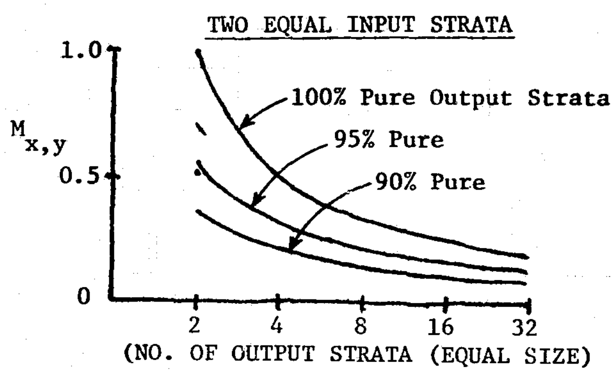
a. INPUT ENTROPY $\Longrightarrow$ $M_X = \frac{I(X;Y)}{H(X)} = 1 - \frac{H(X|Y)}{H(X)}$



b. OUTPUT ENTROPY $\Longrightarrow$ $M_Y = \frac{I(X;Y)}{H(Y)} = 1 - \frac{H(Y|X)}{H(Y)}$



c. TOTAL ENTROPY $\Longrightarrow$ $M_{X,Y} = \frac{I(X;Y)}{H(X,Y)} = \frac{H(X) - H(X|Y)}{H(Y) + H(X|Y)}$



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PLANS

- Assess The Utility Of The Candidate Measures For Evaluating Stratification Performance

- Continue The Development And Applications Of Information Theoretic Measures and Concepts

ERROR MODELING

OBJECTIVES

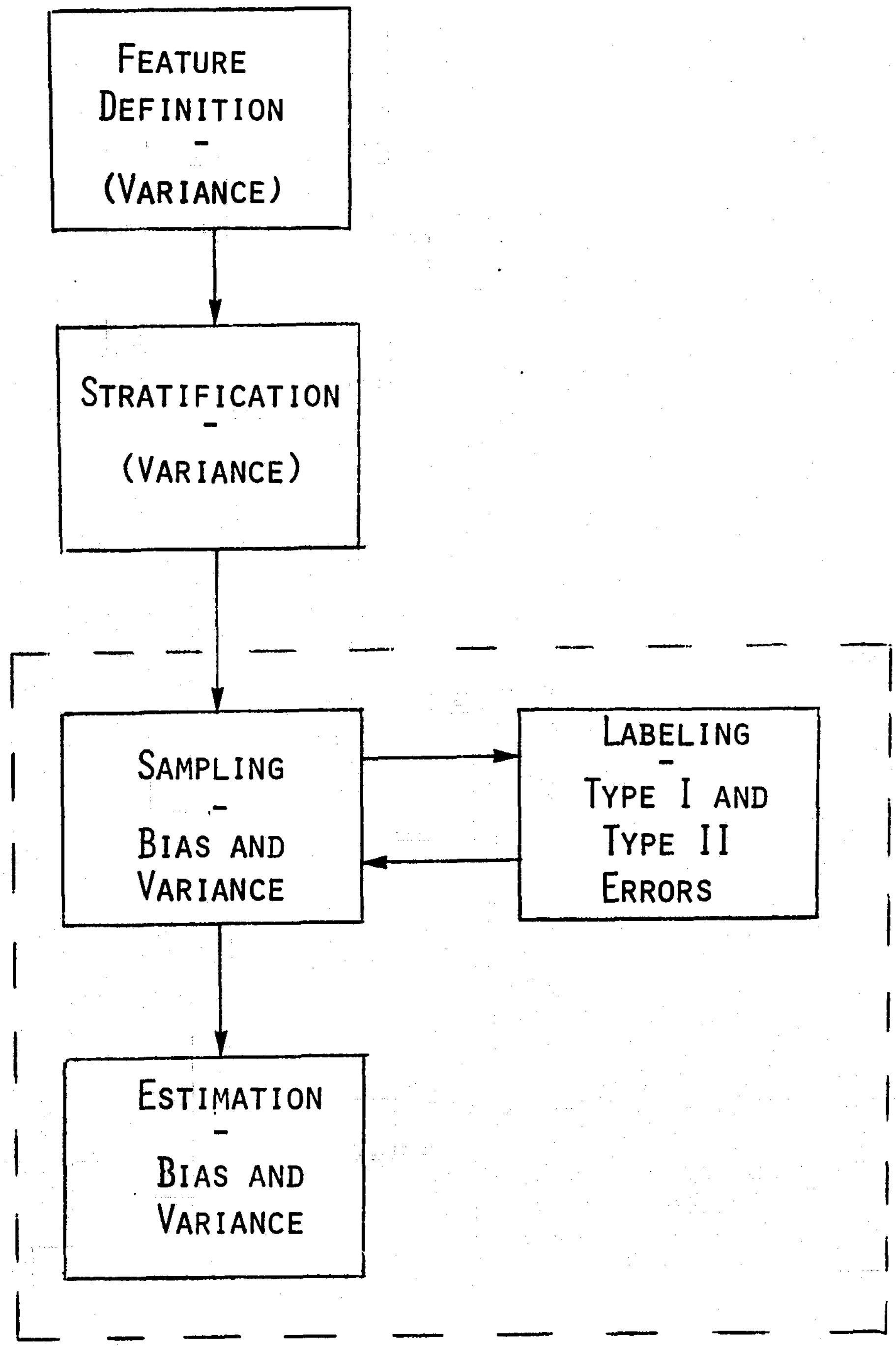
- DEVELOP A CONVENIENT REPRESENTATION OF ERROR SOURCES AND PROPAGATION IN PROCEDURE M
- BROADEN TO INCLUDE A GENERIC CLASS OF AREA SURVEY REMOTE SENSING SYSTEMS
- INVESTIGATE FUNDAMENTAL LIMITS ON ACCURACY OF SYSTEMS

ERROR MODEL

APPROACH

- IDENTIFY THE MAJOR CONCEPTUAL STAGES AT WHICH ERRORS ARISE OR ARE PROPAGATED
- CONSTRUCT ANALYTICAL MODELS OF THE ERROR SOURCES AND PROPAGATION
- FIT THE PARAMETERS OF THESE MODELS FROM EXPERIMENTS TO PRODUCE EMPIRICAL PREDICTIVE MODELS

STAGES IN PROCEDURE M WHICH ARE THE SUBJECT OF AN ERROR MODEL



THE DASHED LINES SURROUND THE COMPONENTS FOR WHICH ERROR MODELS HAVE BEEN FORMULATED.

SYSTEM ERROR MODEL

PROGRESS

PROCEDURE M MODELS FORMULATED:

- SYSTEM BIAS AND VARIANCE AS FUNCTION OF KNOWN TYPE I AND TYPE II ERROR RATES, AT THE STRATA LEVEL.
- SYSTEM BIAS AND VARIANCE AS FUNCTION OF MEAN AND COVARIANCE OF TYPE I AND TYPE II ERROR RATES, AT THE STRATA LEVEL.
- LABELING ERROR MODEL: REPRESENTS TYPE I AND TYPE II ERROR RATES AS A FUNCTION OF COLLATERAL OBSERVABLES (E.G., BLOB SIZE AND SHAPE, ACQUISITIONS USED IN BLOB, ACQUISITIONS USED BY ANALYSTS). THIS MODEL WILL BE FIT TO LABELING EXPERIMENT RESULTS AND TO EXPLAIN THOSE RESULTS. THE MODEL OUTPUT IS THE MEAN AND VARIANCE OF TYPE I AND TYPE II ERROR RATES.

GENERAL MODELS:

- PRELIMINARY FORMULATION OF A MODEL WHICH GIVES BOUNDS ON MAXIMUM SYSTEM BIAS FOR UNKNOWN TRUE PROPORTION AND UNKNOWN BUT BOUNDED TYPE I AND TYPE II LABELING ERROR.

TEST AND EVALUATION

OBJECTIVE

MAINTAIN CLEAR INDICATION AS TO PORTIONS OF PROCEDURE M THAT ARE MOST IN NEED OF IMPROVEMENT, INDICATE CAUSES OR SOURCES OF ERROR, AND IDENTIFY THE NATURE OF PROBLEMS ASSOCIATED WITH EXPANDING LACIE-LIKE TECHNOLOGY INTO NEW CROP TYPE AND REGION ENVIRONMENTS

TEST AND EVALUATION

APPROACH

- CONDUCT ANALYSIS OF ANALYST LABELING OF FIELD TARGETS AND REFINED SPRING WHEAT CONFIGURATION OF PROCEDURE M
  - DESIGN OVERALL EXPERIMENT
  - DEFINE AND EVALUATE ROLE OF ANALYST
  - INSTALL REFINED SPRING WHEAT MACHINE LABELER
  - CONDUCT STATISTICAL AND SUBJECTIVE ANALYSIS OF SOURCES OF ERROR
- EXPLORE MULTICROP APPLICATION OF PROCEDURE M
  - APPLY TO CORN AND SOYBEANS USING GROUND TRUTH LABELS
  - EVALUATE SPECTRAL SEPARABILITY THROUGH ANALYSIS OF SPECTRAL STRATA
  - EVALUATE FIELD SIZE ATTRIBUTES THROUGH ANALYSIS OF SPATIAL STRATA
- TRANSFER PROCEDURE M TECHNOLOGY TO JSC
  - PROVIDE AVAILABLE CODE, TEST BENCH
  - PROVIDE MONITOR INTERFACE BETWEEN QLINE, LARSYS
  - PROVIDE CONSULTATION

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TEST AND EVALUATION

PROGRESS

- ANALYST LABELING/SPRING WHEAT PROCEDURE M EVALUATION UNDERWAY
  - EXPERIMENT DESIGNED
  - 18 SEGMENTS PREPROCESSED
  - ANALYST LABELS FOR ALL BIG BLOBS IN HOUSE
  - PRELIMINARY ANALYSIS BEGUN
- MAJOR STRIDES IN PROCEDURE M TRANSFER UNDERTAKEN
  - CODE TRANSFERRED
  - TEST BENCH PROVIDED
  - MONITOR INTERFACE WRITTEN
  - BLOB NOW OPERATIONAL

ANALYST LABELING/PROCEDURE M EXPERIMENT

FRANK PONT

ANALYST LABELING/PROCEDURE M EXPERIMENT

OBJECTIVES

- UNDERSTAND AI LABELING PROCESS IN A FIELD-LABELING ENVIRONMENT.
- EVALUATE A SPRING SMALL GRAIN CONFIGURATION OF PROCEDURE M USING ANALYST LABELS.
- EXAMINE THE PERFORMANCE OF THE COMPONENTS OF PROCEDURE M.

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ANALYST LABELING/PROCEDURE M EXPERIMENT

OVERALL APPROACH

OBJECTIVE ANALYSIS (USING STATISTICAL METHODS)

- EVALUATION OF LABELING ERROR AS A FUNCTION OF
  - ANALYST
  - SPECTRAL STRATA
  - ADJUSTED PLANTING DATE
  - ACQUISITION HISTORY
  - COLLATERAL DATA
- EVALUATION OF BIAS AND VARIANCE CHARACTERISTICS OF SYSTEM
  - EVALUATE SYSTEM COMPONENTS
  - EVALUATE SYSTEM PERFORMANCE

SUBJECTIVE ANALYSIS (USING ANALYST INTERPRETERS)

- DETERMINE CAUSES OF AI ERROR AND INCONSISTENCY
- DEVELOP OPERATION PROCEDURE M MECHANISM
- EVALUATE PERFORMANCE OF SYSTEM COMPONENTS

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AI LABELING PROCEDURE

- ELEMENTS OF PROCEDURE
  - 3 EXPERIENCED LACIE ANALYSTS
  - ALL BIG BLOBS FOR EIGHTEEN LACIE TY78 BLIND SITES
  - PFC BLOB OVERLAYS, LINE PRINTER MAPS
  - STANDARD LACIE LABELING POCKET
  - COMMENTS FORMS
- PROCEDURE
  - EACH SEGMENT LABELED BY EACH ANALYST INDENPENDENTLY
  - ANALYSTS DEVELOPED LABELING STRATEY
  - EIGHT CODES INDICATING GRAIN, NONGRAIN AND OTHER CHARACTERISTICS ANNOTATED
  - SEGMENT AND OVERALL COMMENT FORMS FILLED OUT BY ANALYSTS

SEGMENT COMMENT FORM FOR PROCEDURE M TEST

1. SEGMENT NUMBER: ____________
2. ANALYST CODE: ____________
3. DATE START: ____________
   COMPLETED: ____________
4. NUMBER OF HOURS REQUIRED FOR LABELING: ____________

5. ACQUISITIONS:

   A.

ACQUISITION DATE	PRIMARY OR SECONDARY	COMMENTS: (SUITABILITY, USEFULNESS, OR REASONS FOR NOT USING)
____________	____________	
____________	____________	
____________	____________	
____________	____________	
____________	____________	
____________	____________	

(USE OTHER SIDE IF NEEDED)

   B. WHAT ARE THE DEFICIENCIES, IF ANY, IN THE AVAILABLE ACQUISITION HISTORY?

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SEGMENT COMMENT FORM FOR PROCEDURE M TEST (CONT'D)

6. COMMENTS ABOUT THE BLOB PATTERNS:

   A. DO THE BLOB INTERIORS SEEM TO BE PURE?

   B. DO THE BLOB PATTERNS MATCH THE FIELD PATTERNS?

   C. WAS THE CHOICE OF BLOB ACQUISITION OPTIMAL? IF NO, WHY? WHICH ACQUISITIONS SHOULD BE USED?

   D. OTHER COMMENTS ABOUT BLOB PATTERNS:

7. GENERAL DESCRIPTION OF SEGMENT. FOR EXAMPLE, MOISTURE, FIELD SIZE, TOPOGRAPHY, PERCENT AGRICULTURE, ETC.

8. DID YOU HAVE TO CHANGE YOUR PROCEDURE IN ORDER TO HANDLE THIS SEGMENT? IF SO, DESCRIBE HOW.

9. OTHER COMMENTS:

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ANALYST OBSERVATIONS/COMMENTS

STRONG POINTS

- BLOBS EASIER TO LABEL THAN DOTS
- BLOBS REPRESENT FIELD CENTERS RATHER WELL

PROBLEM AREAS

- DIFFICULT TO LABEL 300 TO 400 BLOBS
- SMALL BLOBS (L-3 PIXELS) DIFFICULT TO LABEL
- BLOB DOES NOT WORK WELL IN SMALL OR STRIPPED FIELDS
- MIXED BLOBS OCCUR
- ACQUISITIONS USED FOR BLOBBING NOT ALWAYS OPTIMUM
- SINGLE BLOBS MAY BE DISJOINT (DIFFICULT TO LABEL)

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MAJOR COMPONENTS OF EXPERIMENT

- Definition of Field-Like Targets for Labeling
- Definition Of Labeling Procedure
- Analyst Labeling Of Targets
- Pre-Ground Truth Analysis
  - Use Statistical Test To Group Segments Into
    - Those Segments In Which AI Labels Are Significantly Inconsistent and,
    - Those Segments In Which AI Labels Are Relatively Consistant
  - Use AI Provided Segment Information To Determine Cause Of AI Inconsistency/Consistency
  - Obtain Estimates For The Proportion And Standard Deviation Of Spring Small Grain And Spring Wheat
- Ground Truth Analysis
  - Use Statistical Techniques To Determine Relationships Between AI Labeling Error and Collateral Data (Segment Strata and Blob Level)
  - Evaluate Error Propagation Through The Procedure M System And Its Components

ANALYST LABELING ERROR MODEL

GROUND TRUTH LABEL

ANALYST LABEL	SPRING SMALL GRAIN	NON-SPRING SMALL GRAIN
SPRING SMALL GRAIN	α	β
NON-SPRING SMALL GRAIN	$1-\alpha$	$1-\beta$

IF THE PROPORTION OF SPRING SMALL GRAIN IS P

THEN
- THE EXPECTED VALUE OF THE PROPORTION OF BLOBS LABELED SPRING SMALL GRAIN FROM A SAMPLE OF SIZE A IS $\alpha P + \beta(1-P)$
- THE EXPECTED BIAS IS
  $\alpha P + \beta(1-P) - P = (\alpha-\beta-1)P+\beta$
- THE VARIANCE IS

$$\frac{(\alpha-\alpha^2)\ P + (\beta-\beta^2)\ (1-P) + (\alpha-\beta)^2\ \ P(1-P)\ \frac{B-A}{B-1}}{A}$$

WHERE A IS THE SAMPLE SIZE AND
B IS THE NUMBER OF BLOBS.

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STRATUM AND SEGMENT ESTIMATES FOR α, β, AND P

- Denote The Labels From The AI's As $\{C_{IJK}\}$ $\quad I = 1,2,3$

  $J = 1,2,3,\ldots,18$

  $K = 1,2,3,\ldots,N_J$

  N_J = NUMBER OF BIG BLOBS IN SEGMENT J

  WHERE $C_{IJK}=1$ IF THE I^{TH} ANALYST LABELS BLOB K OF SEGMENT J AS SPRING SMALL GRAIN. OTHERWISE, $C_{IJK}=0$.

- The Estimates For α, β, AND P FOR STRATUM S OF SEGMENT J ANALYST I ARE

  – $\hat{\alpha}_{IJS} = \dfrac{\sum W_{KJ} C_{IJK}}{\sum W_{KJ}}$, SUM IS OVER ALL BLOBS K IS STRATUM S WITH GROUND TRUTH GRAIN

  – $\hat{\beta}_{IJS} = \dfrac{\sum W_{KJ} C_{IJK}}{\sum W_{KJ}}$, SUM IS OVER ALL BLOBS K IS STRATUM S WITH GROUND TRUTH NON-GRAIN

  – $\hat{P}_{IJS} = \dfrac{\sum W_{KJ} C_{IJK}}{\sum W_{KJ} C_{IJK}}$, SUM IS OVER ALL BLOBS K IN STRATUM S

  WHERE W_{KJ} IS THE NUMBER OF PIXELS IN BLOB K OF SEGMENT J.

STATISTICAL ANALYSIS OF THE EFFECT OF ACQUISITION HISTORY ON ANALYST'S LABELING

- USING A THEORETICAL BRIGHTNESS-GREENNESS TRAJECTORY FOR WHEAT BLOBS, PLANTING, EMERGENCE, HEADING, TURNING, AND HARVEST DATES CAN BE ESTIMATED. THESE DATES CAN BE COMPARED TO THE ACQUISITION DATES TO DEFINE ACQUISITION DEFICIENCIES.

- FOR BLOB K DEFINE $X_{K1}=1$ IF BLOB K HAS A PREEMERGENCE ACQUISITION DEFICIENCY
  $X_{K2}=1$ IF BLOB K HAS AN EMERGENCE ACQUISITION DEFICIENCY
  $X_{K3}=1$ IF BLOB K HAS A HEADING ACQUISITION DEFICIENCY
  $X_{K4}=1$ IF BLOB K HAS A TURNING ACQUISITION DEFICIENCY
  $X_{K5}=1$ IF BLOB K HAS A HARVEST ACQUISITION DEFICIENCY

- WE CONSIDER THE MODEL

$$\alpha_{KI} = \gamma_0 + \gamma_1 X_{K1} + \gamma_2 X_{K2} + \gamma_3 X_{K3} + \gamma_4 X_{K4} + \gamma_5 X_{K5} + \epsilon_{KI}$$

THE TERMS γ_0, γ_1, γ_2, γ_3, γ_4, AND γ_5 CAN BE ESTIMATED USING LEAST SQUARED REGRESSION.

STATISTICAL BETWEEN-ANALYST COMPARISONS

- COMPUTE $\hat{\alpha}_{IJS}$, $\hat{\beta}_{IJS}$, AND $\hat{P}_{IJS}$ FOR EACH ANALYST-STRATUM COMBINATION OF SEGMENT J.
- WE CONSIDER THE MODELS
  - $\hat{\alpha}_{IJS} = \mu' + \tau'_I + \varepsilon'_{IJS}$, $\hat{\beta}_{IJS} = \mu'' + \tau''_I + \varepsilon''_{IJS}$, $\hat{P}_{IJS} = \mu''' + \tau'''_I + \varepsilon'''_{IJ}$
  - THE VARIANCES OF $\hat{\alpha}_{IJS}$, $\hat{\beta}_{IJS}$, AND $\hat{P}_{IJS}$ DEPEND ON α_I, β_I, P_I, AND BLOB SIZE.
  - THE VARIANCES OF $T(\hat{\alpha}_{IJS})$, $T(\hat{\beta}_{IJS})$, AND $T(\hat{P}_{IJS})$ DEPEND ONLY ON THE BLOB SIZES, WHERE $T(X) = \text{ARCSIN}(\sqrt{X})$.
  - WEIGHTED ANOVA IS APPROPRIATE USING A FUNCTION OF THE STRATUM BLOB SIZES AS WEIGHTS.
- ANOVA ALLOWS US TO DECOMPOSE THE SUM OF SQUARES INTO
  - BETWEEN ANALYST SUM OF SQUARES
  - WITHIN ANALYST SUM OF SQUARES
- THE F-TEST ALLOWS US TO TEST THE FOLLOWING NULL HYPOTHESIS FOR SEGMENT J.
  - H_0': $\tau'_1 = \tau'_2 = \tau'_3 = 0$, H_0'': $\tau''_1 = \tau''_2 = \tau''_3 = 0$, AND H_0''': $\tau'''_1 = \tau'''_2 = \tau'''_3 = 0$.
- THE BETWEEN ANALYST TEST CAN BE USED TO GROUP THE SEGMENTS FOR LATER STUDY

STATISTICAL ANALYSIS OF THE EFFECT OF SEGMENT GROUPING ON ANALYST LABELING

- GROUP SEGMENT BY VARIOUS STATISTICAL AND PHYSIOLOGICAL CRITERIA, E.G.,
  - AI CONSISTENCY
  - DROUGHT STRESS
- GROUP SEGMENTS BY ANALYST PROVIDED CRITERIA
  - PERCEIVED PHYSIOLOGICAL SIMILARITIES
  - PERCEIVED AGRICULTURAL CROPPING PRACTICES
- EVALUATE ERROR AS FUNCTION OF SEGMENT GROUPINGS

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SUMMARY

- Substantial progress is being made in conducting an experiment to understand and evaluate analyst labeling in a field labeling environment and utilizing those labels in a Procedure M environment.

- Subjective analysis by analyst interpreters and analytical analyses using statistical methods are expected to provide insight into the sampling-labeling-estimation process.

ADVANCED TECHNOLOGY

OBJECTIVE

- TO GENERATE VIABLE TECHNICAL OPTIONS FOR LARGE SCALE AGRICULTURAL FORECASTING SYSTEMS BASED ON REMOTE SENSING

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ADVANCED TECHNOLOGY

APPROACH

- SELECT A FEW STUDY TOPICS TYPICAL OF BROAD PROBLEMS ANTICIPATED IN THE 1980-85 TIME FRAME
- USING TECHNIQUES OF GENERAL PROBLEM SOLVING IDENTIFY KEY TECHNOLOGICAL ISSUES WHICH HAVE POTENTIAL TO BE RESOLVED
- OUTLINE CONDITIONS FOR SOLUTION OR SUGGEST APPROACHES TO SOLUTION

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ADVANCED TECHNOLOGY

PROGRESS

- TWO TOPICS
  - USE OF MACHINE PROCESSING TO EXTEND LABEL INFORMATION TO LARGE AREA
  - CONCEPT OF EARLY WARNING
- FIRST TOPIC HAS IDENTIFIED TWO KEY TECHNICAL ISSUES
  - ESTIMATION FROM PRIORS BASED ON COLLATERAL DATA WHEN SPECTRAL DATA ARE MISSING
  - ACCURATE REGISTRATION TECHNIQUES

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KEY THOUGHTS WHICH WE WISH TO LEAVE WITH YOU

- Agronomic Features and Variables are Encoded in Landsat Data Features. Understanding This Code is Central to Successful Labeling.
- Different Features Carry Different Information. No Single Feature Can Satisfy All Needs.
- Identifying Stage of Development is Critical to Successful Crop Discrimination. This Identification Can Be Accomplished.
- Adaptation for Moisture Stress and Soil Brightness Variations is Necessary for Robust Labeling Procedures. These Conditions are Identifiable and Can Be Adapted To.
- Landsat 3 Data is Scaled Significantly Different Than Landsat 2 Data. This Difference Can Be Corrected For.
- There is a Real Cost Associated With Stratification Before Sampling. Even Breaking Even in Sampling Variance Requires Some Finite "Purification" Performance by the Stratification Methodology.
- Currently Demonstrated Stratification Performance Falls Short of the Apparent Potential.
- Measures of Performance are Subtle Creatures. They Must Be Tailored to the Specifics of the Information Desired and the Environment Encountered.
- The Tall Poles to be Overcome in Future Acreage Assessment:
    - Truly Objective Labeling
    - Effective Stratification
    - Understanding of Errors

ON KNOWLEDGE

APPEARANCES TO THE MIND ARE OF FOUR KINDS.

THINGS EITHER ARE WHAT THEY APPEAR TO BE;
OR THEY NEITHER ARE, NOR APPEAR TO BE;
OR THEY ARE AND DO NOT APPEAR TO BE;
OR THEY ARE NOT, AND YET APPEAR TO BE.

TO HIT THE MARK IN ALL THESE CASES, IS THE WISE MAN'S TASK.

DISCOURSES OF EPICTETUS
EPICTETUS OF HIEROPOLIS
50 B.C. - 30 A.D.

"THERE'S NO SUBSTITUTE FOR SIGNATURES"
H. HORWITZ 1979 A.D.

END